INFORMATION TO USERS

The most advanced technology has been used to photograph and reproduce this manuscript from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

U·M·I

University Microfilms International
A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
313/761-4700 800/521-0600

Order Number 9020141

Changes in cognitive appraisals and metabolic indices of physical exertion during a two-hour run

Acevedo, Edmund Osvaldo, Ph.D.

The University of North Carolina at Greensboro, 1989

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

CHANGES IN COGNITIVE APPRAISALS AND METABOLIC INDICES OF PHYSICAL EXERTION DURING A TWO-HOUR RUN

by

Edmund O. Acevedo

A Dissertation Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy

Greensboro
1989

Approved by

Diane L. Gill

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at The University of North Carolina at Greensboro.

Dissertation Adviser Diane L Gill

Committee Members Allan H. Goldfarb

Marian Franklin

8/23/89
Date of Acceptance by Committee

8/21/89
Date of Final Oral Examination

ACEVEDO, EDMUND, O., Ph.D. Changes in Cognitive Appraisals and Metabolic Indices of Physical Exertion During a Two-Hour Run. (1989) Directed by Dr. Diane L. Gill. 104 pp.

During an endurance run various physiological changes occur in response to the metabolic energy demands of the activity, and the runner makes continuous cognitive appraisals of the experience. The purpose of this investigation was to document the changes and relationships in several metabolic indices and cognitive appraisals that occur throughout a two-hour run. More specifically, 12 male competitive runners ran on a treadmill at approximately 70 percent of their maximal oxygen consumption for two hours. The metabolic indices assessed at specific times during the run were heart rate (HR), ventilation (V_E), respiratory quotient (RQ), plasma lactate (La) and plasma glucose (Glu). Simultaneously, cognitive appraisals of exertion (ratings of perceived exertion; Borg, 1962), expectancies (self-efficacy; Bandura, 1977), and affect (profile of mood states; McNair, Lorr, & Droppleman, 1971) were assessed.

Repeated measures ANOVAs revealed significant changes in RQ, V_E, La, Glu and HR. Also, significant changes were observed in vigor, fatigue, tension, and depression, while confusion and anger did not change. The total score for mood state, referred to as total mood disturbance (TMD) demonstrated a significant change toward a more negative mood state. The other cognitive appraisals of RPE and self-efficacy increased and decreased, respectively.

Pearson correlations among variables at specific times of assessment revealed that as exercise continued beyond 30 minutes the magnitude of the relationships among cognitive appraisals (self-efficacy, RPE, TMD) increased slightly. Concurrently, relationships among specific appraisals and specific metabolic indices slightly increased. Generally, stronger relationships occurred among cognititve appraisals than between cognitive appraisals and metabolic indices. Step-wise regressions supported the cognitive appraisal-metabolic indice associations.

ACKNOWLEDGEMENTS

The author wishes to express his sincere gratitude to the following individuals:

Sigma Xi, The Scientific Research Society, for their Grants-in-Aid of Research Award. Without this funding this research would have been difficult to complete.

Dr. Diane Gill for her guidance, helpfulness, friendship and fairness throughout my dissertation project and Ph.D. program.

Dr. Allan Goldfarb for his helpful guidance and assistance in the lab; and for his honesty, sincerity, and friendship.

Dr. Marian Franklin for her support and assistance in helping me to "get what I want".

Dr. Tom Martinek for his advice, guidance and for being an excellent example of a complete professor.

Brian Boyer and Kent Todd for their assistance in the lab and for their support and friendship.

Scott Murdoch for his support and understanding (roommates have it tough when dissertation time comes).

Tracy Acevedo for her support and helpfulness; and more importantly, for the balance and love she brings to my life.

TABLE OF CONTENTS

CHAPTER

LIST OF TABLES

LIST OF FIGURES

FIGURES PAGE

CHAPTER 1

INTRODUCTION

During an exhaustive endurance run various physiological and perceptual changes occur over time. As a run continues, many of the physiological changes occur in an attempt to keep up with the metabolic energy demands of the activity. Additionally, every runner has felt the relaxed ease at the beginning of a run turn into the inescapable discomfort of fatigue as physical limits are reached. This investigation documented the changes in metabolic indices including heart rate (HR), ventilation (V_E), respiratory quotient (RQ), plasma lactate (La) and plasma glucose (Glu). Also, changes in the cognitive appraisals of exertion (rating of perceived exertion), expectations (self-efficacy) and affect (tension, depression, anger, fatigue, confusion, and vigor) at specific times during an exhaustive endurance run were assessed. And finally, this study examined the relationships between these metabolic indices and cognitive appraisals.

This chapter reviews the research on several physiological variables which have demonstrated predictable responses to the metabolic demands during prolonged exhaustive work. The metabolic indices which are reviewed include HR, V_E, RQ, La, and Glu. These indices have been chosen because they have demonstrated predictable changes during prolonged exercise. In addition, these indices have been found to relate to ratings of perceived exertion (RPE) and this investigation examines the possible relationships of RPE and metabolic indices to mood state and self-efficacy. Literature about these cognitive appraisals is also reviewed. However, the changes which may occur in RPE, self-efficacy, and mood state during exhaustive running are not clear. Finally, based upon the research reviewed, the questions being addressed and related hypotheses are presented.

Metabolic Indices and Exhaustive Endurance Work

A person's ability to perform prolonged muscular work is ultimately limited by a myriad of physiological changes with a variety of nonspecific, subjective symptoms subsequently referred to as fatigue or exhaustion. This myriad of physiological changes includes the accumulation of metabolites, depletion of energy yielding substances, structural breakdown in the muscle cell, and alterations in enzyme activity. The physiological changes associated with metabolic demands which were assessed during this study and which are reviewed in this chapter include lactate accumulation, blood glucose, heart rate (HR), ventilation (V_E), and respiratory quotient (RQ).

Lactate Accumulation

Lactate is produced in the muscle cells (Jorfeldt, 1970) when pyruvate, in the presence of NADH (reduced form of nicotinamide-adenine-dinucleotide), is converted by lactate dehydrogenase (LDH) to lactate instead of entering into the mitochondria for oxidative metabolism. This can occur without an oxygen (O_2) deficiency in the muscle, although this reaction is primarily regulated by O_2 demands and hydrogen (H) ion flow. The fate of pyruvate depends on the muscle fiber, NADH levels, oxygen availability and enzyme activity. These factors dictate if pyruvate will enter the Krebs Cycle, the malate asparatate shuttle, the glycerol phosphate shuttle, or be converted to alanine or lactate. Therefore, lactate formation usually occurs when inadequate O_2 available at the working muscle results in a backup in handling H ions in the electron transport chain. This process necessitates an increase in NADH levels slowing down glycolysis (energy production through glucose breakdown). To maintain energy production from glycolysis NADH must be converted to NAD by LDH. This allows glycolysis to continue by regenerating NAD. When lactate accumulates in the muscle to a level greater than the muscle's ability to metabolize it, then the lactate must diffuse into the blood (Jorfeldt, Juhlin-Donnfelt & Karlson, 1978; Koyal, Whipp, Huntsman, Bray & Wasserman, 1976; Simmons, Alpas, Tashkin & Coulson, 1978).

Lactic acid accumulation in the muscle interferes with energy production for continued work (Harper, Rodell & Mayes, 1979) and also hinders FFA mobilization from adipose tissue (Issekutz, Shaw & Issekutz, 1975), thus delaying the point at which lactate accumulates can prolong endurance. By delaying the onset of blood lactate accumulation, a greater percentage of an individual's maximal oxygen consumption can be utilized. This indicates that work may continue at a higher relative intensity before the development of metabolic acidosis.

Astrand, Hallback, Hedman, and Saltin (1963) measured lactate accumulation in cross-country skiers after maximal efforts ranging in distance from 10 to 85 km. Despite maximal effort, lactate decreased with time and distance. After a 10 km distance (35-36 minutes) the average lactate concentration was 139 mg%; after a 30km race (1 hour, 50 minutes) it was 68 mg%; and after a 50 km race (3 hours, 6 minutes), it was 39 mg%. The 85 km race demonstrated even lower lactate levels which was paralleled by a similar drop in RQ, indicating either carbohydrate depletion or greater lipid utilization. These data indicate that as endurance activities continue for a prolonged period of time or distance, intensity of exercise decreases and less lactate is accumulated, which delays metabolic acidosis.

In the past, measurement of RQ from ventilatory exchange served as the basis for determining the contribution of carbohydrates and fats in exercise (Herman, Hultman, & Saltin, 1967; Richter, Sonne, & Christensen, 1981). Research using prolonged exercise as protocol has demonstrated a steady decrease in RQ with endurance exercise (Ahlborg, Felig, Hagenfeldt, Hendler, & Wahren, 1974; Ahlborg & Felig, 1982). With the advanced techniques of arteriovenous measurements, implementation of needle-biopsy techniques for removing tissue, and the use of animal models direct knowledge of the carbohydrate and fat responses in specific tissue to exercise has been advanced.

Blood Glucose and Exercise

Glycogen from contracting skeletal muscle and glucose obtained from the liver via the circulation represent the primary carbohydrate stores available for energy production by working muscle. As exercise continues beyond 90 minutes endurance performance can be dramatically hindered due to the depletion of glycogen from the working muscles and liver. This depletion of glycogen stores leads to a rate of glucose production which can not keep pace with the rate of glucose use and can result in a fall in blood glucose concentration. The development of hypoglycemia in marathon runners (Levine, Gordon, & Derick, 1924) has been recognized for more than 50 years.

After short term exercise, blood glucose concentration will either remain constant or increase (Hermansen, Pruett, Osnes, & Giere, 1970; Wahren, Felig, Ahlborg, & Jorfeldt, 1971; Gollnick, Armstrong, Sembrowich, & Saltin, 1973; Hickson, Hagberg, Conlee, Jones, Ehsani, & Winder, 1979). During prolonged endurance exercise lasting longer than 60 minutes, glucose concentration falls progressively, with the rate of decrease dependent on the intensity of exercise (Pruett, 1970; Ahlborg et al., 1974; Ahlborg & Felig, 1982). However, hypoglycemia at exhaustion is not always observed (Hermansen et al., 1967). This may be due to an inhibition of glucose uptake from the blood stream by increased oxidation of fatty acids in the muscles, by gluconeogenesis in the liver from the glycerol produced in lipolysis, and by lactate and pyruvate produced by working muscles. In addition, elevated ketone levels, which are an alternative substrate for the central nervous system (Owen, Morgan, Kemp, Sullivan, Herrera, & Cahill, 1967), could diminish or delay the symptoms of hypoglycemia.

Because the primary substrate which the brain uses for energy is glucose it is suggested that hypoglycemia causes central nervous system dysfunction. Evidence for this is demonstrated by the relationship between hypoglycemia and cognitive function and mood state (Krall, 1978). Symptoms of hypoglycemia include nervousness, anxiety, sweating, dizziness, weakness, irritability, lack of concentration, and impaired judgment. However, for these symptoms to become apparent glucose levels must fall below a critical level of 40 milligrams per deciliter of whole blood. This level of glucose is rarely observed following endurance exercise.

Heart Rate

From the information presented it can be seen that fatigue is closely related to the extent to which the capacity of the cardiovascular system to transport oxygen is stressed. When exercise is relatively intense (50% of maximal oxygen consumption) then impingement of blood flow to organs such as skin, kidneys, and liver may have significance in the etiology of fatigue. Additionally, depending upon the percent of maximal oxygen uptake utilized, body temperature can rise to high levels. In this case the cardiovascular system is presented with a dual task: (a) Continued adequate transport of oxygen and metabolic substrate to all organs both working and those not directly involved in exercise; (b) Adequate blood flow for conduction of heat from the body core to the surface to minimize thermogenic stress.

Adolph (1947), in examining the rise in heart rate, has noted that a 1.5 % decrease in body weight caused by thermal dehydration produced an increment in heart rate of about 10 beats/min. Although a fall in blood volume may contribute to an increase in HR in the early minutes of exercise under normal conditions, heart rate continues to rise despite a stable plasma volume after five to ten minutes. A possible contributory cause for increased HR is an increase in body temperature with increased blood flow to the skin. Rowell and colleagues (1966; 1974) found that when men are heated by raising ambient or surface temperature during exercise, central blood volume and stroke volume decrease and cardiac output is maintained by increased HR.

Ventilation

Simonson (1978) suggests that the factors involved in exercise hyperpnea (deep and rapid breathing) are grouped in three categories including reasonably certain, inconstant, and problematical. The reasonably certain category contains all neurogenic factors (reflexes from joints and muscles, irradiation of cortical impulses to the reticular formation, and afferent nerve impulses aroused in air passages). In the second category are chemical stimuli (partial pressure of carbon dioxide and oxygen and hydrogen ions) in arterial blood. However, exercise hyperpnea can exist without any of these being involved. The third category includes possible impulses from chemoreceptors or pressoreceptors. Because these factors are involved in the development of fatigue as work continues at the same work load, then it may be expected that fatigue is also associated with an increase in pulmonary ventilation. The increase in pulmonary ventilation with the onset of fatigue has been demonstrated

(Hanson, Cleremont, Dempsey, & Reddan, 1982; Thompson, Dempsey, Chosy, Shahidi, & Reddan, 1974).

Summary

In summary, during a prolonged endurance event physiological changes occur. The research has demonstrated an increase in HR and V_E, a decrease in RQ and Glu, and depending on the individual's relative exercise intensity either an increase or no change in La. In addition, an individual may make several cognitive appraisals which may relate to these metabolic indices and performance. These include RPE (an evaluation of effort), mood state (an appraisal of affect), and efficacy expectations. However, the relationships between lactate accumulation, blood glucose, HR, V_E, RQ, RPE, mood state, and self-efficacy are unknown.

Cognitive Appraisals during Exercise

The most extensive research on cognitive appraisals during exercise has focused on RPE. However, other cognitive appraisals which relate to performance may also occur. These include self-efficacy and mood state. The following is a review of the literature on exercise, RPE, self-efficacy and mood state.

Ratings of Perceived Exertion

In 1962 psychologist Gunner Borg introduced the Perceived Exertion scale which was designed to measure an individual's perception of exertion during physical work.

This scale was constructed to increase linearly with the exercise intensity for work on a cycle egometer. This was a convenient way of constructing a scale because oxygen consumption and heart rate increase linearly with work load. The scale values range from 6 to 20 and can be used to denote heart rate ranging from 60 to 200 beats per minute for 30 to 50 year old subjects, making the scale easier to use. However, Borg (1962) stressed that this close relationship was not to be taken too literally because heart rate can be affected by other factors such as age, type of exercise, environment, and anxiety.

Since this scale's introduction much research has accumulated. For the most part the scientists who have studied perceived exertion are exercise physiologists interested in the physiological independent variables that explain the perceptual response. Also, physiologists have used perceived exertion to try to explain theoretical problems that lie outside the main themes of that discipline. Morgan (1981) has suggested that perceived exertion offers an excellent means for studying exercise within a psychophysiological context. He further stated:

> ...the psychophysical judgement is best viewed as a Gestalt, and this product involves the interactive configuration or processing of numerous input parameters such as muscle and blood lactate, ventilatory minute volume, catecholamine production, blood glucose levels, muscle glycogen stores, personality structure, pain tolerance, past experiences and memory, and probably opioid and neurotransmitter levels

> in the brain. In other words, the product (perceived exertion) is based upon a psychophysiological process which is technologically inaccessible, but readily available in terms of one's self-awareness. (p. 424).

Some researchers have focused on how physiology is related to ratings of perceived exertion (RPE) while others have approached RPE as a psychophysiological construct, and still others have focused on the specific psychological counterpart of this perceptual experience. These different approaches have added much to the understanding of an individual's RPE which in turn has led to various models to better explain and predict the construct.

A plethora of research has accumulated in the area of physiological variables related to RPE, both central (sensations or feelings primarily associated with the cardiorespiratory system) and local factors (sensations from exercising muscles and joints). Ekblom and Goldbarg (1971) were the first to formally propose a two-factor model for evaluating RPE during exercise. Two published reviews have evaluated the influence of local and central factors on the perception of effort (Mihevic, 1981; Pandolph, 1978). Also, a symposium published in <u>Medicine and Science in Sport and Exercise</u> (Cafarelli, 1982; Robertson, 1982) has reported the contributions of local and central signals to the perception of effort. These reviews demonstrate ample support for the relationship between local factors and RPE. However it must be noted that most of this experimental evidence is correlational in nature and does not imply causality.

Henriksson and coworkers (1972) demonstrated that at equivalent metabolic rates, RPE was lower for concentric work than eccentric work performed on a bicycle. Also at equivalent power outputs at two pedaling rates (30 and 60 rpm) RPE's were lower at 60 rpm. These authors suggested that signals from mechanoreceptors, golgi tendon organs, and/or differences in muscle tension are important sensory inputs. The possible importance of feelings of strain in the working muscle was also cited by Ekblom and Goldbarg (1971) when comparing RPE for bicycling, arm cranking, running and swimming. Pandolf and Noble (1973) have proposed that somatic sensations from joint capsules, ligaments and proprioceptive muscle and tendon sensors are more important cues for RPE at 40 rpm than at 60 and 80 rpm at equivalent power outputs and metabolic rates. Lollgen and coworkers (1975) found similar results supporting further the significance of local factors for RPE.

Studies (Allen & Pandolf, 1977; Edwards, Melcher, Hesser, Wegertz, & Ekelund, 1972; Ekblom & Goldbarg, 1971; Gamberale, 1972; Pandolf, Cafarelli, Noble, & Metz, 1972) have identified a possible relationship between blood lactate and RPE. Allen and Pandolf (1972) recorded a high correlation between blood lactate and RPE at the end of submaximal exercise. Also, when arm and leg work were compared, RPE did not differ for a given blood lactate concentration (Ekblom & Goldbarg, 1971). Bicycling and treadmill exercise revealed similar results. Pandolf and coworkers (1972) have speculated that RPE may be related to anaerobic metabolites during heavy work.

Catecholamines also have been reported to relate to RPE. The use of vanilmandelic acid (VMA) as an estimate of urinary catecholamine excretion has suggested a possible relationship between decreases in VMA and decreases in RPE (Docktor & Sharkey, 1971). Frankenhaeuser and associates (1969) proposed a similar relationship suggesting that adreneline release involved feelings of emotional stress or unpleasantness.

Support for local factors as a major signal or cue of physical work has been presented. However, other researchers (Kay & Shepherd, 1969; Lollgen, Graham, & Sjogaard, 1980; Sargent & Davies, 1973) have presented data or arguments refuting the relationship of local factors to RPE. These articles are few, but do give reason for more carefully designed experiments to fully understand the effects and mechanisms behind the relationship of local factors and RPE. For example, Kay and Shepherd (1969) reported that the correlation coefficient between RPE and lactate concentration was not significant after 5 minutes of submaximal exercise.

The related research supporting or disputing central factor involvement in the exertional estimates during physical exercise is inconclusive. Furthermore, many of these proposed cardiopulmonary cues, when manipulated experimentally were not found to be primary factors determining the perception.

Pioneering work of Borg (1962, 1970) suggested the relation between HR and RPE during physical work. However, more evidence exists that disputes central factors than disputes local factors. Martin (1981) demonstrated that after acute sleep loss VO_2 and HR during exercise were unchanged, but subjects reported significantly greater RPE. Davies and Sargeant (1979) using intravenous injections of atropine and practolol to alter autonomic nervous system activity, concluded that HR is not related to RPE. Similarly, Sjoberg and coworkers (1979) employing a single intravenous dose of propanolol concluded that HR has little influence on effort sensation. Squires and his coworkers (1982) investigating the effects of propranolol on RPE soon after myocardial revascularization surgery demonstrated similar results. HR did not change although RPE did under posthypnotic suggestion during exercise for Albert and Williams (1975). Jackson, Dishman, La Croix, Patton, and Weinberg (1981) noted a linear increase for HR and RPE as a function of time and distance during a 1.5 mile run, although the relationship was low ($r = .16$). Furthermore, reviews by Mihevic (1981) and Robertson (1982) have concluded that it does not appear as if HR and absolute VO_2 are associated with pronounced central signals of exertion.

Most of the literature on central factors seems to support the importance of ventilation and respiratory effort as central signals (Horstman, Morgan, Cymerman, and Stokes, 1979; Martin, 1981; Mihevic, Gliner, & Horvath, 1981; Pederson & Welch, 1977; Robertson, 1982; Young, Cymerman, & Pandolf, 1982). For example Martin (1981) reported both RPE and minute ventilation were significantly higher during exercise after acute sleep loss. However, in this case, Martin and Gaddis (1981) could not reproduce similar results. Pederson and Welch (1977) have demonstrated a strong relationship between RPE and V_E while breathing hyperoxic gas mixtures during exercise. Mihevic, Gliner, and Horvath (1981) suggested that the decrements in pulmonary function associated with breathing ozone was reflected by perception of effort though changes may have been related more to alterations in respiration rate than V_E. Young, Cymerman, and Pandolf (1982) provided compelling evidence for the relationship between respiratory effort and central effort by using acute and chronic hypoxic exposure to environmentally manipulated physiological responses to exercise.

Sensations associated with breathing would appear to be the only central cues that are consciously monitored during exercise. In combination, the research supports the contention that local signals dominate the perception of effort at all exercise intensities while ventilatory cues become more prominent at the higher exercise intensities.

Using the research literature in RPE, Pandolf, Burse, and Goldman (1975) proposed an experimental model for evaluating differentiated RPE. This model suggests that undifferentiated RPE from the Borg scale belongs to the "superordinate" level of subjective reporting which represents the overall body responsiveness resulting from the integration of various sensory cues. These sensory cues at the superordinate level of subjective reporting are not close to the underlying physiological demands. This model, by utilizing "subordinate", differentiated ratings, which appear to be in close proximity to the level of the "discrete symptoms", suggests that the relationship between perceptual ratings and physiological cues during exercise can be more closely defined and compared. Also it encourages comparisons between local and central factors with contrasts to general or overall exertion. This model goes further in stressing the importance of associated behavioral states which results in task aversion or alter motivation fostering a psychobiological approach to RPE.

Psychologists have suggested that knowing what a person "thinks" he/she is doing may be more important than what he/she "is" doing. Morgan and Borg (1970) have supported this by presenting data showing that subjective perceptual ratings of effort expenditure can be employed as an effective predictor of maximal performance. Psychologists have proposed that one's perceptual experience may be mediated by psychological factors because physiological variables have accounted for appoximately 60% of the variance in RPE. More specifically, personality variables, past experience, motivation and emotional factors may contribute to RPE.

For example Morgan (1973) has demonstrated that extroverts at heavy workloads tend to underestimate RPE. In the same article Morgan (1973) presented data suggesting that anxious neurotics and depressives tend to underestimate RPE. In addition, individuals classified as type A have reported lower fatigue ratings at similar oxygen consumptions than individuals classified as type B (Carver, Coleman, & Glass, 1976). Also past experience may mediate RPE in the case of a person who may not have had sufficient experience with fatigue like symptoms that occur with physical exertion. Similarly, when an event is inconsistent with expectations derived from knowledge about past experience, causal attributions to effort are most common (Spinks, 1978).

Motivational factors also seem to affect RPE. This is suggested by attribution research reporting that effort ratings are higher after success than after failure (Bird & Brame, 1978; Forsyth & Schlenker, 1977; Scanlan & Passer, 1980). Self-presentational strategies can also affect an individual's self-report (Bradley, 1978), although based on existing data from other fields predictions are difficult to make. Emotions may affect an individual's RPE and is a topic unresearched and worth pursuing.

Rejeski (1981) has proposed a framework for the integration of physiological and psychological factors. This model suggests that as intensity and/or duration of exercise increases, the relative importance of physiological input to cognitive variables increases as a function of an undefined mathematical relationship. To accommodate individual differences at both the physiological and psychological levels, a range of tolerance becomes an integral part of the model. This threshold zone accounts for the potential shifts in a person's tolerance to exertion and may be caused by either situational variables (social facilitation) or physiological input (aerobic vs. anaerobic). Rejeski (1981) mentions further that "the intent here is to attune researchers to the scope of perceived exertion, rather than specify the nature of this process in a limited context" (p.315).

To observe the effects of changes in perception on physiological variables Morgan, Hirota, Weitz and Balke (1976) performed a series of experiments involving hypnotic suggestions. These experiments involved cycling at an absolute workload for either 5 minutes or 20 minutes while under hypnotic suggestion of light, moderate or heavy exercise. In both experiments, the RPE decreased significantly following the suggestion of light exercise. Also HR and ventilatory responses followed these same patterns during the short term exercise, while during longer term exercise (20 minutes) only V_E followed the RPE pattern. Morgan concluded from these studies that RPE appears to involve a cognitive-perceptual process rather than perception alone.

In studying the effect of meditation practice on selected ventilatory responses and RPE while cycling, Cadarett and coworkers (1982) had meditators and controls who had similar ventilatory responses during light exercise, exercise for 20 minutes. Meditators exercised with simultaneous practice of meditation, while controls simply exercised. The respiratory rate, minute ventilation and ventilatory equivalent for oxygen decreased and total volume increased significantly for meditators over controls. This study offers further support for the input from ventilatory sensation as important cognitive-perceptual cues.

Morgan, Horstman, Cymerman, and Stokes (1983) hypothesized that performance gains are mediated via a cognitive perceptual process based upon distraction. Subjects were asked to attend to a mantra in synchrony with each leg movement, concentrate vision on a self-selected object and ignore uncomfortable sensory input. These subjects did not differ in their exercise HR, O_2 consumption, ventilation, or lactate production although the dissociation group had increased catecholomine responses. Withstanding more stress could explain the increase in catecholomine levels because the dissociation group also exercised for a longer period of time (7 minutes). Morgan et al. (1983) concluded that a cognitive strategy based upon dissociation of sensory input facilitates endurance performance.

Some research suggests a relationship between painlessness, the endogenous opioids and exercise (Black, Chesher & Stamer, 1979; Haier, Quaid & Mills, 1981). Farrell and coworkers (1982) noted lower RPE's with higher levels of plasma beta endorphin levels. McMurray and coworkers (1987) have demonstrated a parallel increase in endorphin concentration and RPE at 40, 60, and 80 % of max but not at max. However, this research is far from conclusive.

The research on RPE is quite extensive. Studies of local and central factors associated with RPE suggest that local factors are dominant at all workloads while central factors, ventilation in particular, may act as ampliphiers to local factors as aerobic demand increases during exercise. More controlled studies could offer information on the relationship between lactate accumulation, catecholomine production and RPE during exercise. This would provide insight into the body's stress response, metabolic alterations, and RPE. However, the area of research which can provide the most interesting information for pracical use, is that on the psychological aspects of perceived exertion. Studies in this area could provide information on the relationships between RPE and personality structure, peak performance, adherence, past experience and emotion.

To realize that psychological aspects of RPE may account for 40% of the variance offers an exciting challenge to the researcher interested in understanding the relationship between RPE and performance. However, it must be noted that RPE has both psychological and physiological components and should be researched from a multidimensional perspective.

This study examined the changes in RPE during a prolonged endurance run. In addition, this study investigated the relationships of HR, V_E, RQ, La, Glu, self-efficacy, mood state, and RPE throughout the exhaustive run.

Efficacy Expectations

Bandura's (1977) self-efficacy theory was developed out of his social learning theory. It recognizes that behavioral, cognitive, physiological, and environmental influences all interact and function as determinants of each other. The theory postulates that people's perceptions of their capabilities affect whether they will approach or avoid a task and how long they will persist. Expectations of personal efficacy are derived from four principal sources of information: past performance accomplishments, vicarious experience, verbal persuasion and physiological state.

Performance accomplishments provide the most influential source of efficacy information because they are based on one's mastery experiences (Bandura, Adams, & Beyer, 1977; Biran & Wilson, 1981; Feltz, Landers, & Raeder, 1979). These mastery exeriences affect self-efficacy judgements through the cognitive processing of this information. Experiences which are perceived as successes will raise efficacy expectations conversely experiences perceived as failures will lower expectations. The influence of performance accomplishments also depends on the perceived difficulty of the task, the effort expended, the amount of physical guidance received, and the patterns of success and failure (Bandura, 1982).

Self-efficacy appraisals can also be influenced by vicarious experience. Observing or visualizing other similar individuals perform successfully can raise self-efficacy in observers (Bandura, Adams, Hardy, & Howells, 1980; Kazdin, 1979). By the same token, observing others perceived to have similar ability fail despite a good effort lowers the observer's efficacy expectations and undermines their effort (Brown & Inouye, 1978).

A person's beliefs can also be influenced by the use of persuasive techniques. If the heightened appraisal, stimulated by the verbal persuasion, is within realistic bounds it can contribute to increases in self-efficacy and successful performance. However, unrealistic beliefs of personal competence invite failure that will discredit the persuaders and undermine the recipient's self-efficacy.

Bandura's (1986) final source of information which provides an indication of self-efficacy is the level and quality of physiological arousal. Arousal affects behavior through the cognitive appraisal of the information conveyed by arousal. For example, arousal before performance may be interpreted as fear of performing poorly or as being psyched up and ready to perform at an optimal level. Physiological sources of self-efficacy also include levels of fatigue, fitness, and pain in strength and endurance activities (Taylor, Bandura, Ewart, Miller, & Debusk, 1985).

Bandura (1986) states that the cognitive processing of efficacy information involves two separate acts: The first concerns the types of information people attend to and use as indicators of personal efficacy. Each of the four sources of information has its distinctive set of efficacy indicators. The second concerns the combination rules or heuristics an individual employs for weighting and integrating efficacy information from different sources in forming their self-efficacy judgments. These judgements are a cognitive appraisal of information which is being selected, weighted and integrated. Cognitive appraisals are affected by personal, social, situational and temporal circumstances under which events occur.

Bandura (1982) suggests a microanalytic methodology for testing propositions about the origins and functions of perceived self-efficacy. This analysis requires detailed assessment of the level, strength, and generality of perceived self-efficacy. Level of self-efficacy refers to a person's expected performance attainments. Strength refers to the strength of a person's beliefs that they can achieve different levels of performance. And, generality reflects the number of domains of functioning in which an individual judges themselves efficacious. Self-efficacy measures are constructed by listing a series of tasks varying in difficulty, complexity, or stressfulness. Individuals are asked to specify the tasks they believe they can perform (level). Then, for each task specified, they rate their degree of certainty (strength) that they can accomplish the task on a 100 point probability scale ranging from high uncertainty to complete certainty.

This method requires that the researcher conduct a conceptual analysis of the subskills needed to perform a task and a contextual analysis of the level of situational demands. However, in the sport literature, self-efficacy researchers have typically correlated total self-efficacy scores with total performance scores rather than examining the congruence between self-efficacy and performance at the level of individual tasks (Wuertle, 1986). Feltz (1988) has suggested that perhaps this is due to the nature of the tasks used in sport. In most studies done in sport, subjects' efficacy expectations and performance have not been assessed in terms of the approach/avoidance to a series of tasks that increase in difficulty. Instead, subjects are asked their confidence beliefs concerning a single task in terms of how long or at what height they can perform and then are asked to perform that task in subsequent trials.

Self-efficacy in Sport

To examine self-efficacy in sport and motor performance researchers have examined either the effects of various methods used to create athletic competence or the relationship between self-efficacy and performance. One or more of the four major sources of efficacy information, discussed by Bandura are the basis for the various treatment techniques examined in this research.

Studies in sport and exercise research that have examined the influence of techniques based on performance accomplishments have shown them to be effective in enhancing self-efficacy and performance (Ewart, Taylor, Reese, & DeBusk, 1983; Feltz, Landers, & Raeder, 1979; Hogan & Santomier, 1984; Kaplan, Atkins & Reinsch, 1984; McAuley, 1985; Weinberg, Gould, & Jackson, 1979; Weinberg, Gould, Yukelson, & Jackson, 1981; Weinberg, Sinardi, & Jackson, 1982). Other researchers have supported the superiority of performance-based information over other sources of information (Desharnais, Bouillon, & Godin, 1986; Feltz & Mugno, 1983). And information gained through vicarious experiences has been shown to increase perceived efficacy in muscular endurance tasks (Gould & Weiss, 1981), gymnastic performance (McAuley, 1985), exercise activity (Corbin, Laurie, Gruger, & Smiley, 1984), and competitive persistence (Weinberg et al., 1979). These techniques include modeling (Corbin et al., 1984; Gould & Weiss, 1981) and information acquired about a competitor's competence (Weinberg et al., 1979). Few studies have investigated persuasive techniques and self-efficacy in sport. Wilkes and Summers (1984) are the only ones to report persuasive self-efficacy techniques (positive self-talk) influence performance while other studies using positive self-talk (Weinberg, 1986) and reinterpretations of arousal as a source of efficacy information have not reported a significant influence on performance.

In the few studies investigating the influence of physiological or emotional states on self-efficacy (Feltz, 1982; Feltz & Mugno, 1983; Kavanagh & Hausfeld, 1986) the lack of effects may be due to the confounding relationship of actual performance in studies with multiple performance trials. Feltz (1982; Feltz & Mugno, 1983) has investigated the influence of physiological states on self-efficacy and found that actual physiological arousal did not predict efficacy expectancies. Perceived autonomic arousal was a significant predictor of self-efficacy but not as strong as previous performance accomplishments. Additionally, Kavanagh and Hausfeld (1986) found that neither happy nor sad moods, as measured by self-report, alter efficacy expectations.

As Wurtele (1986) has noted in a review, a number of studies have examined the relationship between self-efficacy and athletic or exercise performance. The results of these studies show a significant relationship between efficacy and performance across a number of sport tasks and physical activities. However, as Wurtele (1986) has pointed out, these correlational results do not necessarily demonstrate a causal relationship between self-efficacy and performance.

To investigate the causal relationships in Bandura's theory, several studies (Feltz, 1982; Feltz & Mugno, 1983; McAuley, 1985) in the sport and motor performance area have used path analysis techniques. These studies have found self-efficacy to be an important determinant of performance. Additionally a direct effect of modeling on performance was found (McAuley, 1985) and of past performance on future performance (Feltz, 1982; Feltz & Mugno, 1983). These results indicate that performance-based treatments affect behavior through other mechanisms as well as perceived efficacy expectations.

Although several investigators have examined self-efficacy in sport and factors relating to self-efficacy in sport, the relationship of self-efficacy to physiological variables, RPE, and mood state has not been investigated. This investigation examines the changes in self-efficacy during prolonged endurance running and the relationship of self-efficacy to HR, V_E, RQ, La, Glu, RPE and mood state throughout an exhaustive endurance run.

Mood and Exercise

When trying to determine the effects of exercise on psychological well-being and mood it is important to realize the strengths and weaknesses of the research that has been published. Although many health professionals stress the benefits, both physical and psychological, of exercise, and the phenomenon is frequently noted in the literature (Brunner, 1969; Morgan, Roberts, Brand, & Feinerman, 1970; Morgan, Roberts & Feinerman, 1971; Roth, 1974), the research basis for the psychological benefits in most cases is weak.

Folkins and Sime (1981) have noted that the research has not been performed as true experiments in which pre and post tests are administered to randomly assigned treatment and control groups. Without these conditions internal validity is threatened by history, maturation, test-taking effects, instrumentation, statistical regression to the mean, selection bias, and selection-maturation interaction. Pre- and posttraining studies offer the most useful information although without an integrated theoretical model one can not claim cause and effect relationships. Additionally, fitness effects can not be assumed when comparing fit to unfit groups. Psychological training effects should be substantiated with physiological alterations. Another question that must be addressed is the type, duration, intensity, and frequency of exercise needed to obtain changes in mood.

Taking these design considerations into account, aerobic exercise seems more likely to produce acute mood enhancement than nonaerobic activities (Brown, Ramirez, & Taub, 1978; Morgan, Roberts,& Feinerman, 1970; Sime, 1977). Reviews by Berger (1984), Buffone (1984), and Dishman (1985) support the following conclusions. First, acute vigorous exercise is associated with significant decreases in state anxiety and muscle tension. Secondly, chronic vigorous exercise is associated with significant decreases in state anxiety and muscle tension. And finally, chronic physical activity is associated with significant decreases in depression and depressive symptoms in patients who have been diagnosed as clinically depressed.

Acute and chronic decreases in state anxiety and tension have been attributed to several biochemical and psychological mechanisms although researchers have not yet supported these hypotheses with experimental data. Investigation into plausible explanations for the common observation that vigorous, acute and chronic physical activity improves affective states has approached the issue from three hypotheses. The distraction hypothesis maintains that distraction from stressful stimuli, as opposed to exercise, is responsible for the improved affect associated with exercise. Another hypothesis states that increases in neurotransmitters are responsible, and this is referred to as the monamine hypothesis. The third hypothesis, the endorphin hypothesis, specifies that morphine-like substances are released, which have the ablility to reduce the sensation of pain and produce a state of euphoria.

These hypotheses open the gates to researchers interested in determining the underlying "causes" of the positive affect experienced after vigorous exercise. Pre/post assessments have offered insight into the exercise-mood relationship. However, examining mood changes and physiological adaptations during exercise may provide further information, and researchers may then examine further the other possible effects of exercise through controlled experimental research.

The changes in mood which may occur throughout and after an endurance activity can be measured with a tool which has been previously used with athletes (Morgan & Pollock, 1977), The Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1971). This measure is a valid and reliable assessment of an individual's state of tension, depression, anger, vigor, fatigue, and confusion. In addition, this instrument can be used to assess total mood disturbance (TMD) which is a combined score of the six moods (tension, depression, anger, fatigue, confusion, vigor).

Morgan and Pollock (1977) have assessed runners, wrestlers and rowers using the POMS. Results demonstrated that all three groups of athletes scored similarly. The athletes scored appreciably below the population mean for tension, depression, fatigue, and confusion, and above the mean for vigor. This positive mental health profile and the observed psychometric configuration has been described by Morgan as the "iceberg" profile.

Changes in mood state during exercise have not been examined. In addition, factors relating to mood state during exercise have not been investigated. This study examines the changes in mood state during exercise and the relationship of HR, V_E, RQ, La, Glu, self-efficacy, and RPE during an exhaustive endurance run.

Summary

In summary, during a prolonged endurance event physiological changes occur. Bandura's self-efficacy theory suggests that these are subject to an individual's cognitive appraisal which in turn affects a person's efficacy expectations. In addition, an individual may make several other appraisals which may relate to performance. These include RPE, an evaluation of effort, and mood state, an appraisal of affect. Previous research in sport and exercise science suggests several physiological and psychological changes can be expected. However, it is unknown what relationships may exist between lactate accumulation, blood glucose, HR, V_E, RQ, mood states, self-efficacy, and RPE.

Statement of the Problem

In an attempt to investigate the factors relating to an individual's cognitive appraisal during a prolonged endurance event it is necessary to consider the effects of changing physiology upon an individual's cognitive appraisal of that exerience during that experience. Several areas of research have attempted to link physiological changes with perceptual interpretations. According to Bandura's theory these relationships exist and influence an individual's self-efficacy. Endurance exercise seems to offer a unique physiological experience in which cognitive appraisals would relate to self-efficacy. Thus, it was the purpose of this investigation to examine the changes over time of La, Glu, HR, V_E, RQ, RPE, mood states (tension, depression, anger, vigor, fatigue, confusion and TMD) and self-efficacy. In addition, this study investigates the relationships of these variables as exercise progresses for a prolonged period of time.

Hypotheses

As time progresses during a two hour run:

1. La and Glu will decrease.
2. HR and V_E will increase.
3. RQ will decrease.
4. Mood states will not change.
5. RPE will increase.
6. Self-efficacy will decrease.

Because this investigation is exploratory in nature, and has as its purpose the identification of the relationship of variables throughout an exhaustive endurance run directional hypotheses are not proposed. Instead the following questions were addressed:

1. What is the relationship among HR, V_E, RQ, Glu, La, self-efficacy, RPE, and TMD at various points during a prolonged endurance run?
2. Which variables (HR, V_E, RQ, Glu, La, RPE, TMD) predict self-efficacy at various points during a prolonged endurance run?

3. Which variables (HR, V_E, RQ, Glu, La, self-efficacy, TMD) predict RPE at various points during a prolonged endurance run?
4. Which variables (HR, V_E, RQ, Glu, La, self-efficacy, RPE) predict TMD at various points during a prolonged endurance run?

Limitations

This is an exploratory investigation which has as its primary emphasis the prediction of a construct from a limited number of specific antecedents conceptually linked to that construct. Therefore, it is highly unlikely that all variations can be accounted for. This study concentrates upon those variables which have been empirically connected to the construct in previous research. A second limitation involves the degree of generalizability from the results of this investigation. The relationship of specific physiological variables to cognitive appraisals may not be the same for noncompetitive individuals or individuals participating in other activities.

CHAPTER II

METHOD

Subjects

The subjects for this study, 12 male distance runners, were recruited from personal contacts and announcements at running club meetings in the Greensboro, North Carolina, area. All the subjects were actively involved in training (at least 25 miles per week) and competitive racing. Each subject was informed of all the procedures and risks associated with participation in this study prior to signing a consent form (Appendix A). The extent of their involvement and their right to terminate participation was explained both verbally and in written form in accordance with the procedures filed with the School of Health, Physical Education, Recreation and Dance, Human Subjects Review Committee.

Pilot Study

Two subjects participated in a pilot study. This study was conducted to determine the most efficient and appropriate procedures for assessing cognitive appraisals and metabolic indices during running on a treadmill. The technique that was used required the subject to read the measure from a posterboard. In addition, it was determined that conversation between experimenters and subjects should be kept to a minimum. Also the order of assessments was determined to conserve time and limit confusion for the subject. The first subject was eliminated, and the second was included in the final analyses because the procedures were consistent with those followed throughout the remainder of the study. Upon completion of the pilot study the following procedures were identified and used to conduct the this investigation.

Protocol

The subjects participated in two test sessions conducted in the Human Performance Laboratory at the University of North Carolina at Greensboro. During the first session the subjects completed a medical history form (Appendix B) prior to the maximal oxygen consumption test with electrocardiogram (ECG) monitoring. In an attempt to decrease anxiety, they were shown the catheter and the measures which were used during the second session - the POMS (Appendix C), RPE (Appendix D), and the self-efficacy measure (Appendix E).

The second session was a submaximal (approximately 70 to 75%) run for two hours. To obtain baseline glucose values the subjects were asked to fast for 12 hours prior to this run and to return to the lab for a morning run. Upon their return to the lab they were informed of all the procedures for this session. In addition, they were told that conversation between experimenters and subject would be minimal to standardize the procedures for all subjects. Conversation was limited to assessment procedures and periodic checks on how the subjects were doing on the treadmill (i.e., Is everything O.K.?). After the subjects were informed of the procedures, they completed the POMS. Then a trained phlebotomist inserted the catheter into an antecubital vein in the arm of choice. After a resting blood sample (6 ml) was drawn, the subjects rested for 15 minutes while being prepared for ECG monitoring. A resting HR was taken while the subjects stood on the treadmill, before a short warm-up. The subjects then completed the POMS, and another resting blood sample was drawn. As the subjects began to run they were monitored for oxygen consumption to assure that the submaximal run was between 70 and 75%. At 30 min, 60 min, 90 min, and 120 min, HR was assessed; then the subjects completed the RPE, POMS, and self-efficacy measures; V_E, RQ, and O_2 were measured; and the treadmill was slowed to obtain a blood sample. At the end of the run, after a short cool down, the subjects were asked to lie down for a 15 minute recovery, concluding with the last assessment of the POMS, self-efficacy and a blood sample (see Figure 1).

Cognitive appraisals were taken at rest by having the subjects read the measure from a clipboard held by the experimenter. The subjects reported to the experimenter, and the experimenter recorded the response to limit the subjects' movement. While running, the subjects verbally responded to the measures written in letters approximately 2 inches high on a poster board that was approximately 7 feet in front of the subjects. The POMS was assessed with 5 items on each piece of poster board. The experimenter stated the number corresponding to each mood, the subjects responded and the experimenter recorded the response.

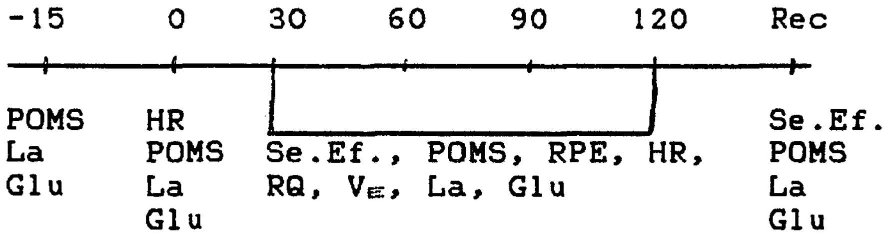

Figure 1. Experimental procedure for second session.

Dependent Measures

Maximal Oxygen Consumption

During the first session each subject's maximal oxygen uptake was determined by a graded exercise protocol run to exhaustion on a motor-driven treadmill. Once the subjects warmed-up, VO_2 max was measured during a continuous run at a constant speed; the grade was increased 2% every 2 minutes until the subjects either reached volitional exhaustion or VO_2 leveled off (<2ml/kg/min).

Heart Rate, Respiratory Quotient, and Ventilation

The ECG was continuously monitored with chest electrodes on a Quinton 3000 and recorded for 10 to 15 seconds every minute during the VO_2 max test and every five minutes during the submax endurance run. Throughout the run, heart rate was monitored visually and calculated from R-R intervals when necessary. Oxygen uptake, carbon dioxide output, and pulmonary ventilation were determined by open-circuit spirometery. Fractions of expired oxygen and carbon dioxide were measured by the Beckman OM-11 and LB-2 CO_2 gas analyzers respectively. These analyzers were calibrated with previously analyzed known gases prior to each testing session. Ventilatory volume was obtained from expired air using a Pneumoscan S-301 spirometer. RQ was determined by dividing VO_2 into VCO_2.

Lactate and Glucose

Blood samples were obtained from a catheter inserted into an antecubital vein in the arm. The phlebotomist withdrew blood at the specified times through the catheter in the vein while the subjects continued to run. If necessary the subjects stopped momentarily while the blood was drawn. Blood samples (10 x 6ml of blood = 60 ml) were drawn using sterile needles and procedures.

The samples were analyzed for hematocrit (Hct; the percentage of blood that is cells) and hemoglobin (Hb; protein in blood cells responsible for oxygen transport) to correct for plasma volume shifts. Hct was determined in duplicate by the microhematocrit method and Hb by the cyanomethemoglobin method. Percent change in blood volume (BV) and plasma volume (PV) were calculated according to the method of Dill and Costill (1974). Lactate was assayed using the LDH method (Sigma, 1987) and glucose using a Sigma Chemical Kit (1986).

Cognitive Appraisals

The self-efficacy measure used for this study assessed efficacy expectations for running performance in a manner similar to that employed by Bandura (1977). The self-efficacy measure consisted of asking the subjects to rate the strength of belief that they could accomplish each of five running speeds for the following 30 minutes. The tasks on the self-efficacy measure were listed in hierarchical order. The fourth task was the pace which the runners maintained to consume 70-75% of their max VO_2. The third was a task which was five seconds per mile faster than the pace they maintained at 70-75 percent, and the second and first were 10 and 15 seconds faster per mile respectively. The fifth task was five seconds slower per mile than the speed they were running. For tasks which the subjects thought they could perform, they rated how certain they were that they could perform that task on a 100-point probability scale. A rating of 100 points indicated absolute certainty, whereas a rating of 10 points indicated the subjects were highly uncertain they could perform the task. Self-efficacy was assessed by totaling these certainty ratings across items and then dividing by the total number of items on the measure.

The shortened version of the POMS (Shacham, 1983) which has been found to be a valid and reliable measure of moods was used as a quick and economical way of identifying and assessing fluctuating affective states. The POMS has 37 adjectives which are associated with one of six moods (tension, depression, anger, vigor, fatigue, and confusion). Respondents described how they felt "right now" on a 5-point likert scale ranging from 0 (not at all) to 4 (extremely). In addition, total mood disturbance (TMD) was determined by adding the five negative moods (tension, depression, anger, fatigue, confusion) and subtracting vigor from this sum to attain a total score.

RPE was obtained during submaximal exercise in an attempt to characterize the manner in which these runners process sensory information relating to physical effort. The RPE values were obtained using the psychophysical category scale developed by Borg (1962). The RPE scale ranges from 6 to 20, and the odd numbered categories have verbal anchors (7 = very, very light; 9 = very light; 11 = fairly light; 13 = somewhat hard; 15 = hard; 17 = very hard; 19 = very, very hard). Participants were instructed to estimate how hard they felt the work was and were told that this assessment should include total inner feelings of exertion, combining all sensations and feeling of physical stress and effort.

Statistical Analysis

To determine changes across time separate one-way repeated measure ANOVAs were computed for the self-efficacy measure, RPE, TMD, HR, RQ, V_E, La and Glu. Separate ANOVAs were also computed for the TMD components of tension, depression, anger, vigor, fatigue, and confusion.

Pearson product-moment correlation coefficients were computed to assess the relationships among self-efficacy, RPE, TMD, HR, RQ, V_E, La, and Glu at each time of assessment.

To determine which combination of variables contributed the most to the cognitive appraisals of mood, efficacy and ratings of physical effort, separate regression equations were developed for each cognitive appraisal at each assessment time. HR, V_E, RQ, La, Glu, self-efficacy and TMD were the predictors for the dependent variable of RPE at each time of assessment; HR, V_E, RQ, La, Glu, RPE, and TMD were the predictors for self-efficacy; and finally, HR, V_E, RQ, La, Glu, RPE and self-efficacy were the predictors for TMD.

The descriptive data is expressed as means and standard errors of the mean. The level of significance was set at $p < .05$ for all analyses.

CHAPTER III

RESULTS

Statistical analyses of the descriptive data collected for this study is included in this chapter. The data is expressed as means and standard errors of the means. For all statistical analyses the level of significance was set at $p<.05$. The data which has been plotted on figures 2 through 10 can be found in Appendix F.

Relevant characteristics of the 12 subjects for this study can be found in Table 1. The mean age of the subjects was 29.92 and this experienced group (9.67 years of running experience) had performed well in marathons (2:40:36) and 10km races (33:23). In addition, they had maintained their training (45.75 miles per week) and had a mean maximal oxygen consumption of 64.64 ml/kg/min. The subjects for this study were to run on the treadmill at 70% of max VO_2 (45.24 ml/kg/min). Actual data revealed that the subjects ran at 72.13% (46.55 ml/kg/min) to 72.9 (47.12 ml/kg/min) with a treadmill speed of 8.53 miles per hour.

Changes in Cognitive Appraisals

Figures 2 through 8 depict the changes in moods which occurred over the two-hour run for these runners. Significant changes occurred with depression, $\underline{F}(6, 66)$ =

Table 1

Subject Characteristics

Variables	*M*	SE
Age	29.92	1.81
Yrs Run Exp	9.67	1.09
Miles/wk	45.75	5.41
26.2 PR	2:40:36	4.37
6.2 PR	33:23	.57
Max VO_2 (ml/kg/min)	64.64	1.48
Max HR (beats/min)	193.5	2.11
70% of Max (ml/kg/min)	45.24	1.04
VO_2 on Tdml (ml/kg/min)	46.85	1.24
Speed of Tdml (miles/hr)	8.53	.19

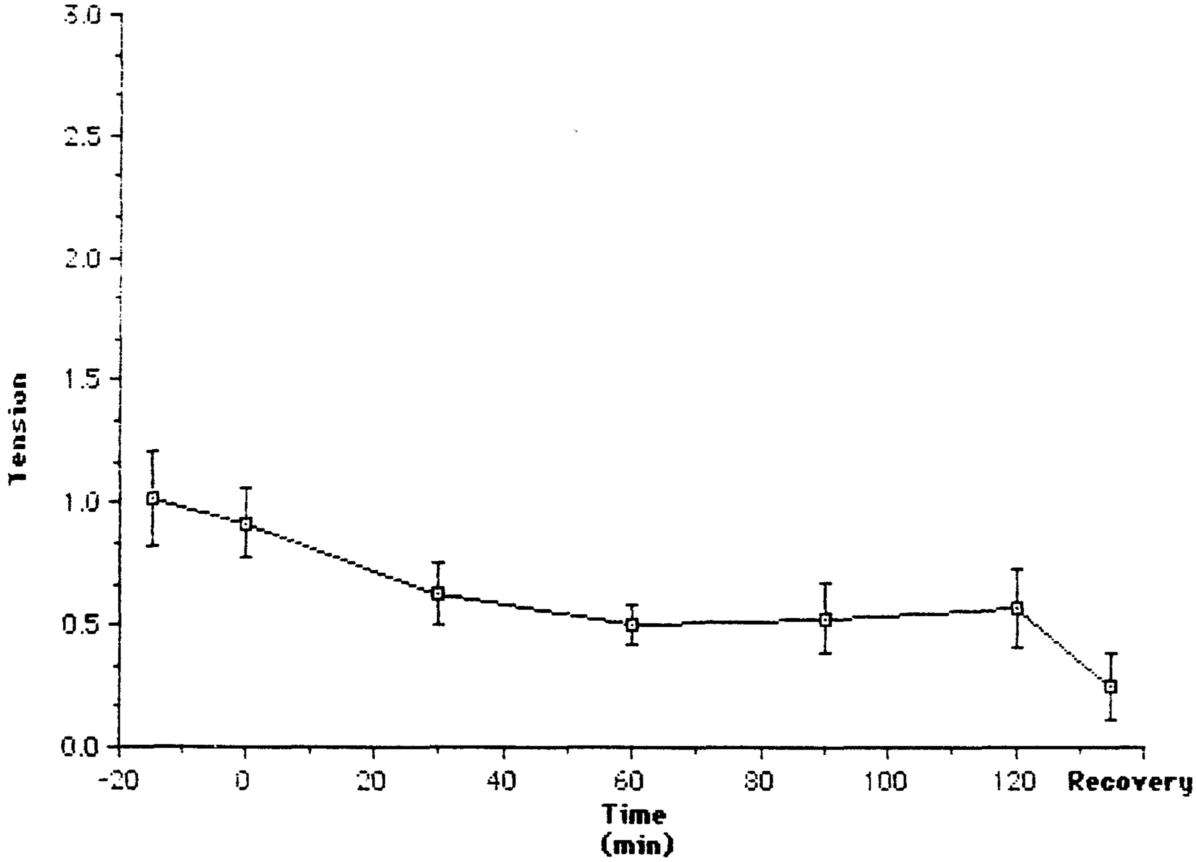

Figure 2. Changes in tension over time (n=12).

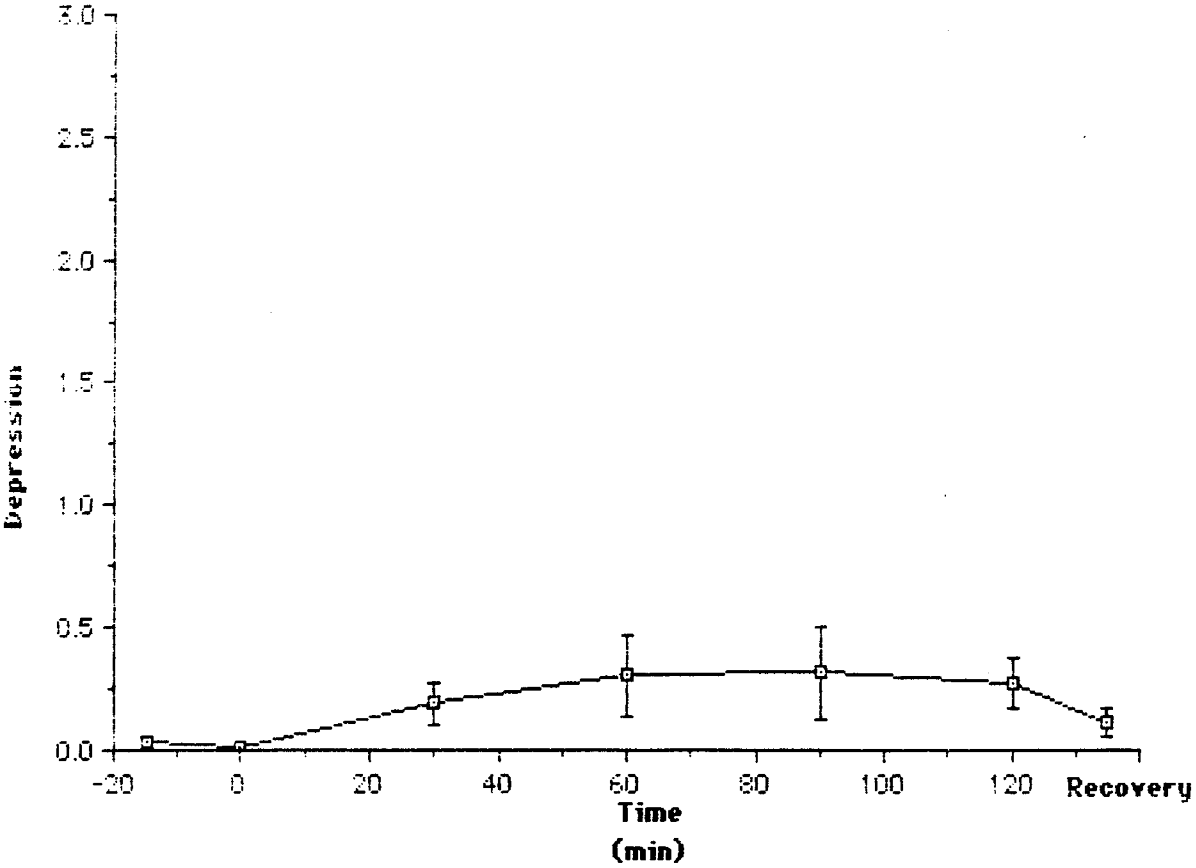

Figure 3. Changes in depression over time
(n=12).

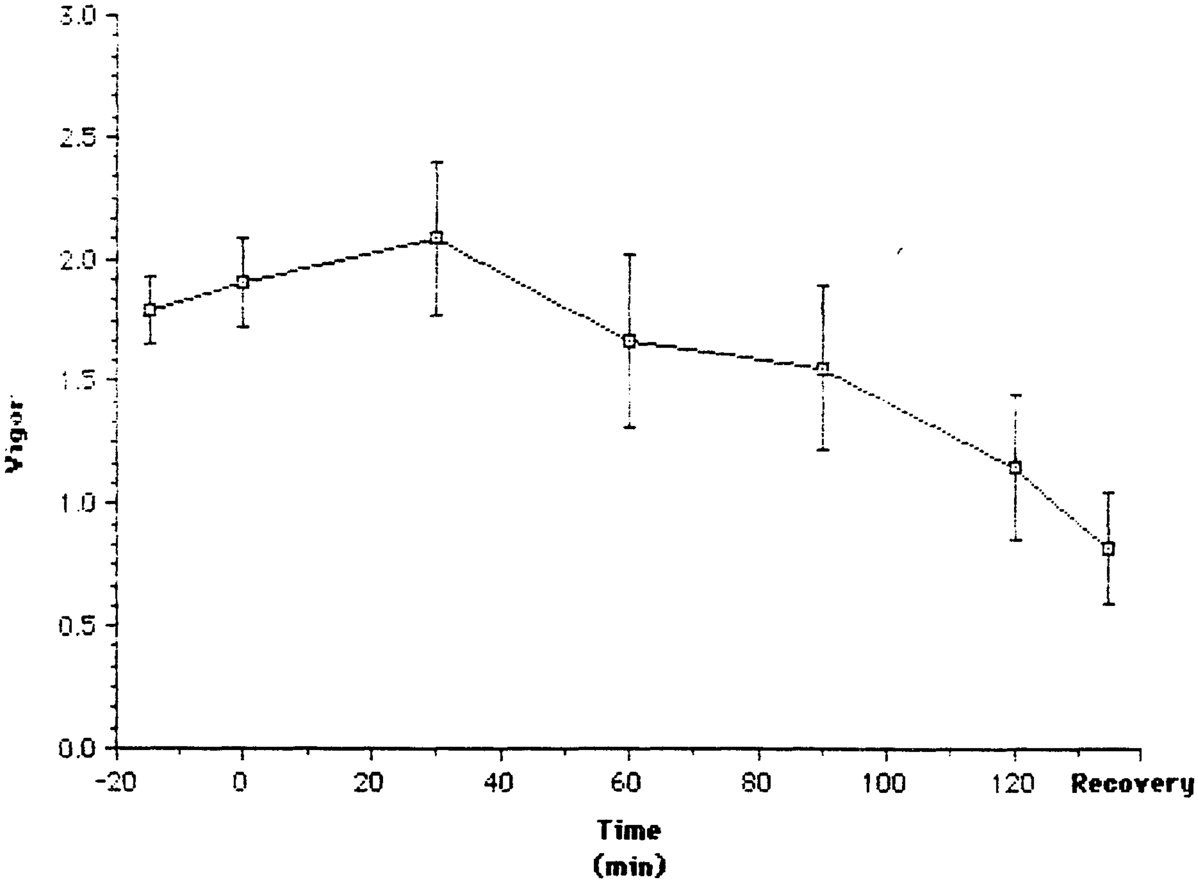

Figure 4. Changes in vigor over time
(n=12).

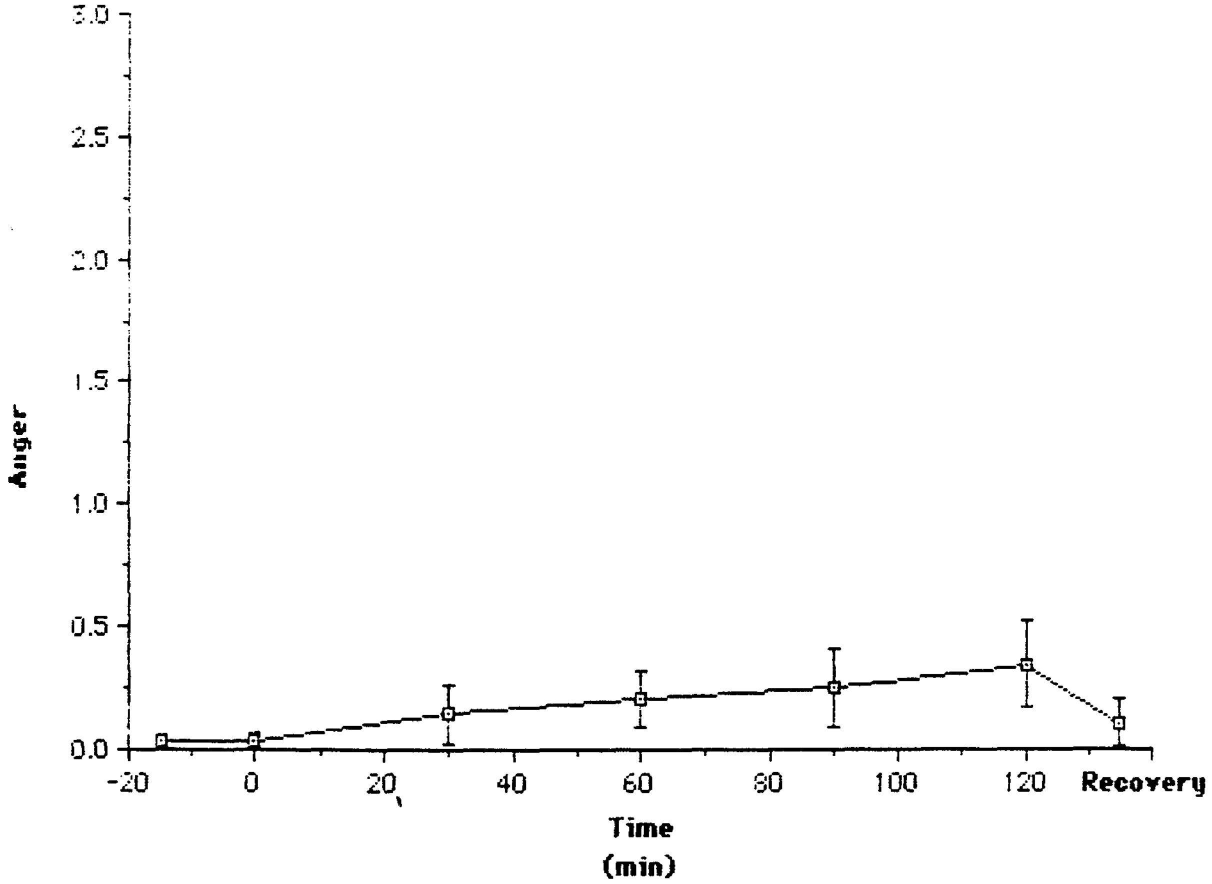

Figure 5. Changes in anger over time (n=12).

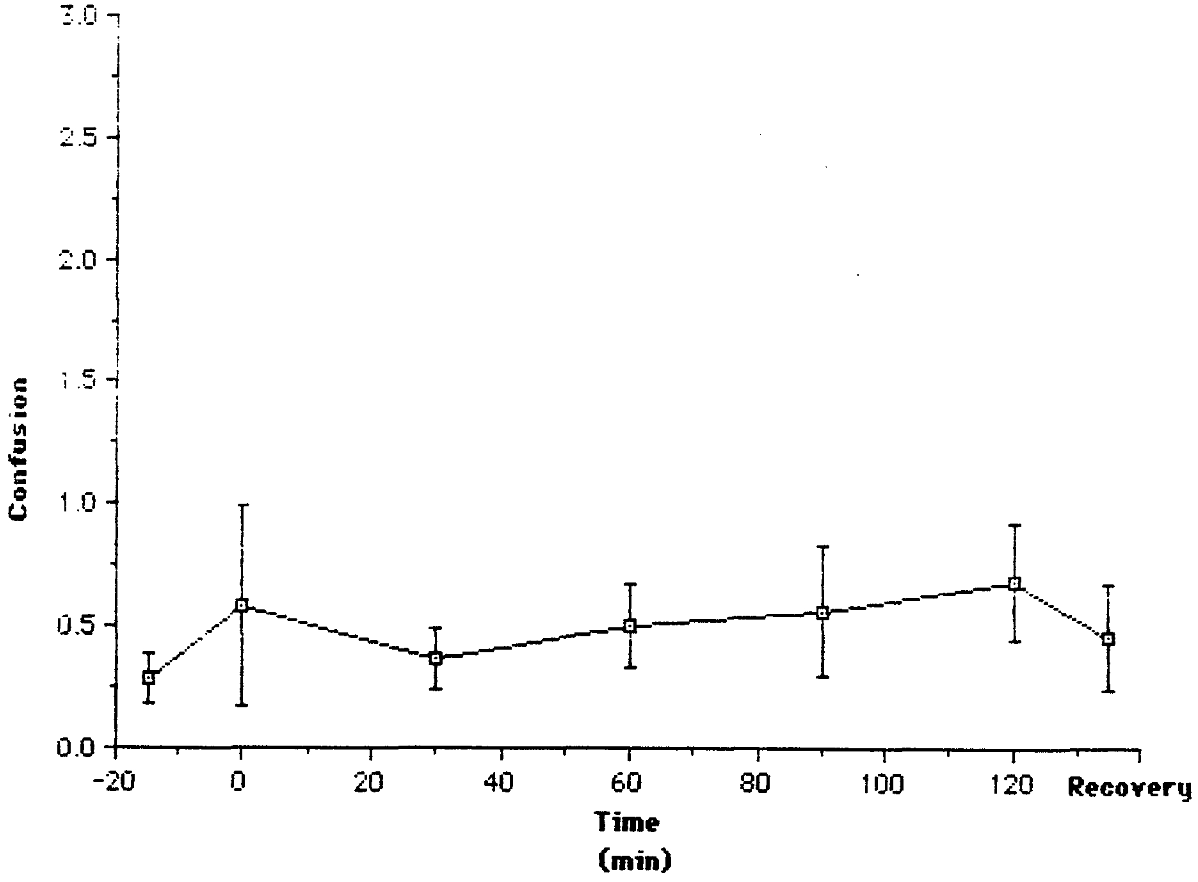

Figure 6. Changes in confusion over time (n=12).

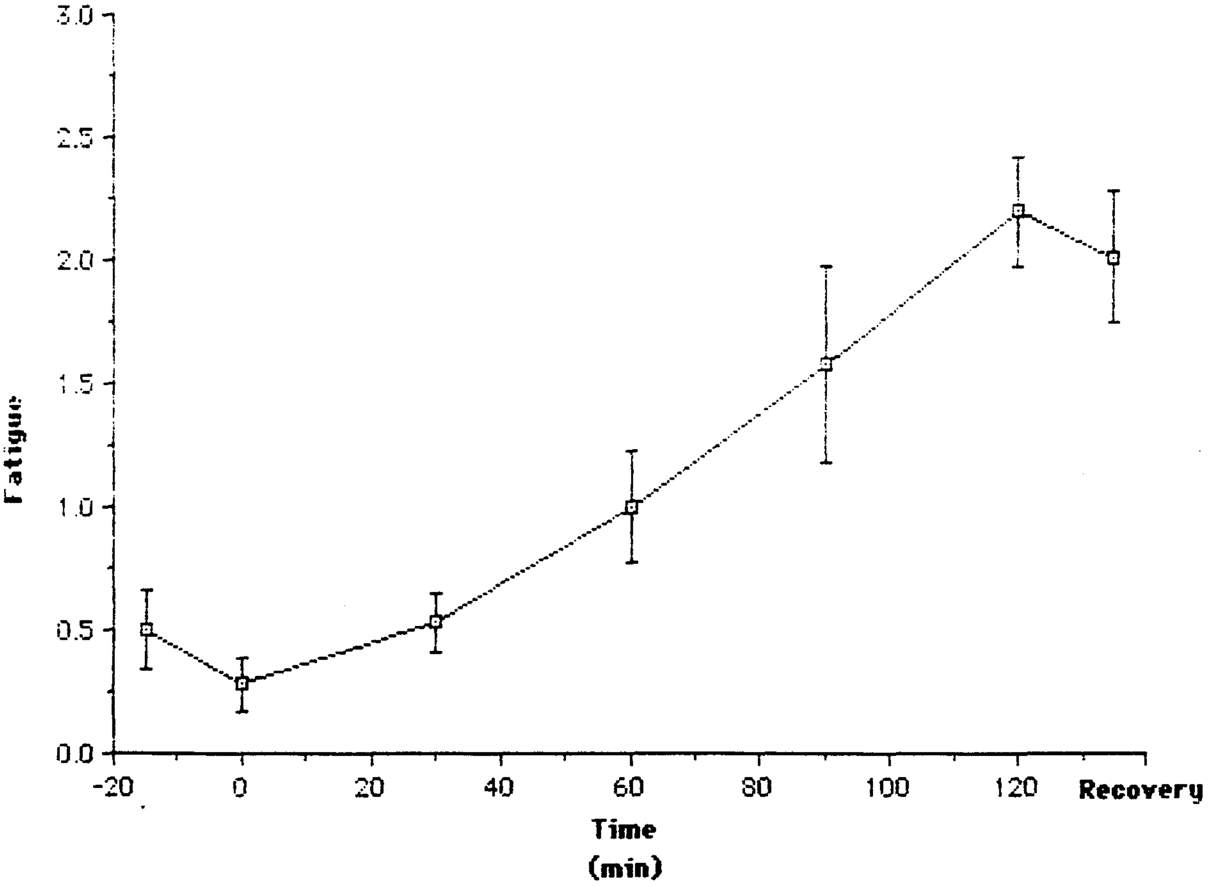

Figure 7. Changes in fatigue over time (n=12).

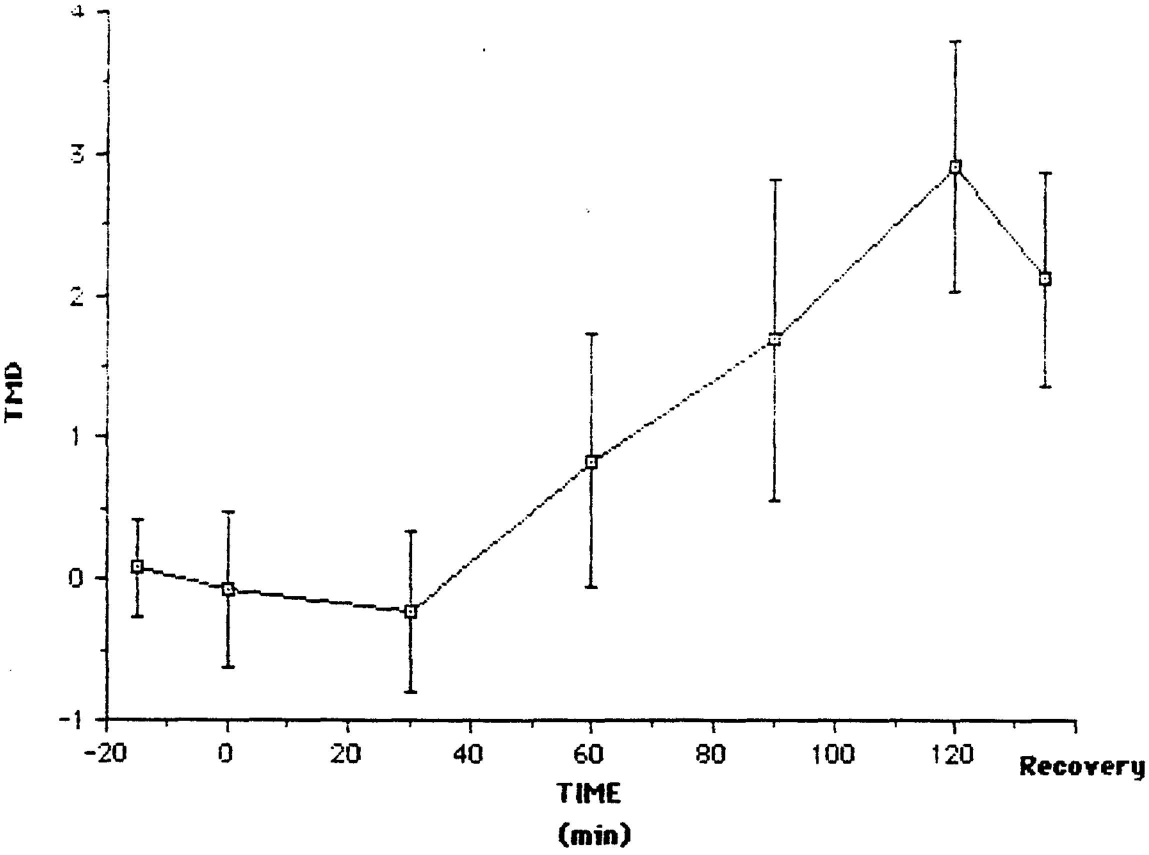

Figure 8. Changes in TMD over time
(n=12).

2.33; tension, *F*(6, 66) = 7.72; fatigue, *F*(6, 66) = 16.09; vigor, *F*(6, 66) = 46.33; and TMD, *F*(6, 66) = 6.46. Tukey post hoc comparisons revealed no significant changes in depression. However, tension decreased significantly from Time 0 to recovery. Also, fatigue increased from Time 0 to Time 90, Time 120, and recovery while vigor decreased from Time 0 to Time 120 and recovery. Post hoc comparisons for TMD revealed increases from Time 0 to Time 120 and recovery.

The cognitive appraisals of RPE, *F*(3, 33) = 25.84, and self-efficacy, *F*(4, 44) = 20.95, (Figures 9 and 10) also changed significantly across time. Tukey comparisons revealed RPE increases from Time 0 to Times 60, 90, and 120. Self-efficacy decreased significantly from Time 0 to Time 120 and recovery.

Changes in Metabolic Indices

Of the metabolic indices assessed (HR, V_E, RQ, La, Glu, VO_2); all but VO_2 demonstrated significant changes across time. Figures 11 through 16 depict those changes. Lactate decreased significantly, *F*(6, 24) = 2.73; however, Tukey post hoc comparisons did not reveal any significant differences between means. Glucose values decreased significantly, *F*(6, 24) = 3.65, with differences occurring between Time 0 and Time 120 and between Time 0 and recovery. V_E increased during exercise, *F*(3, 33) = 4.26, with Time 30 significantly different from Time 120.

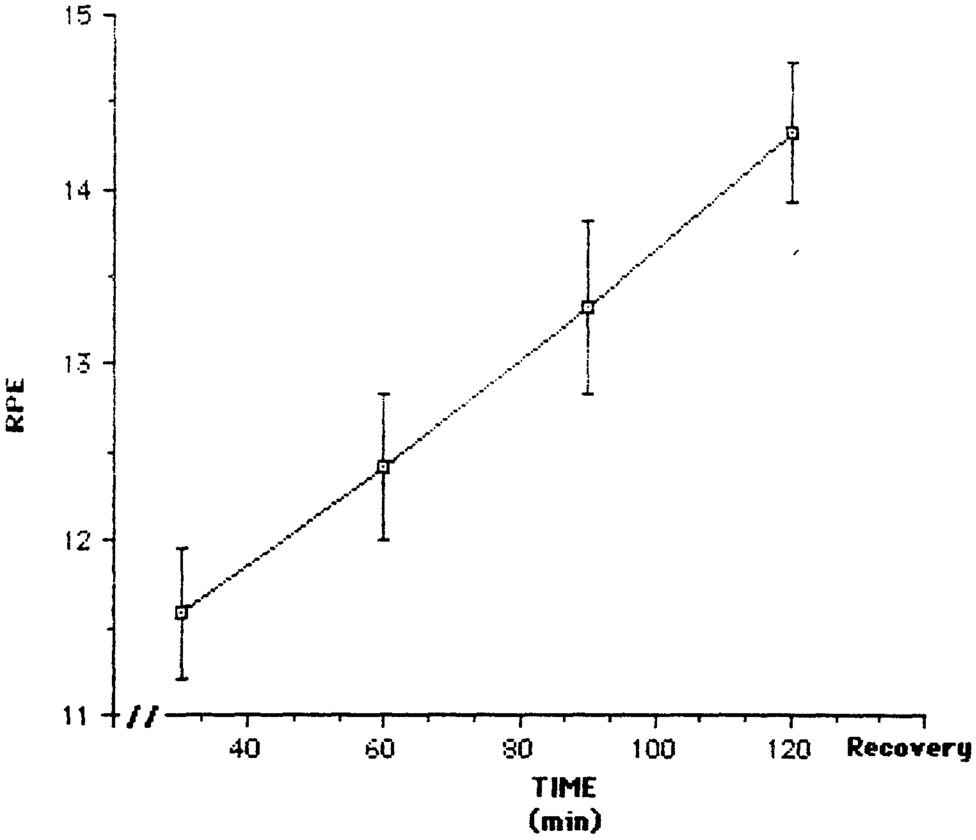

Figure 9. Changes in RPE over time (n=12).

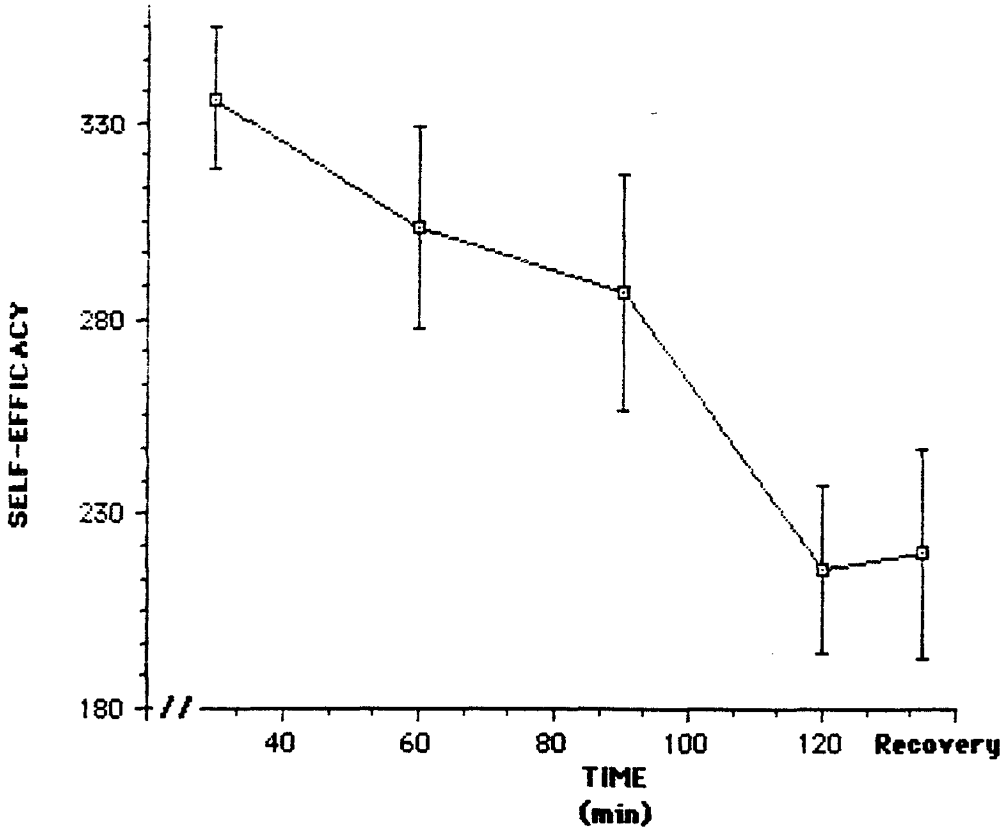

Figure 10. Changes in self-efficacy over time (n=12).

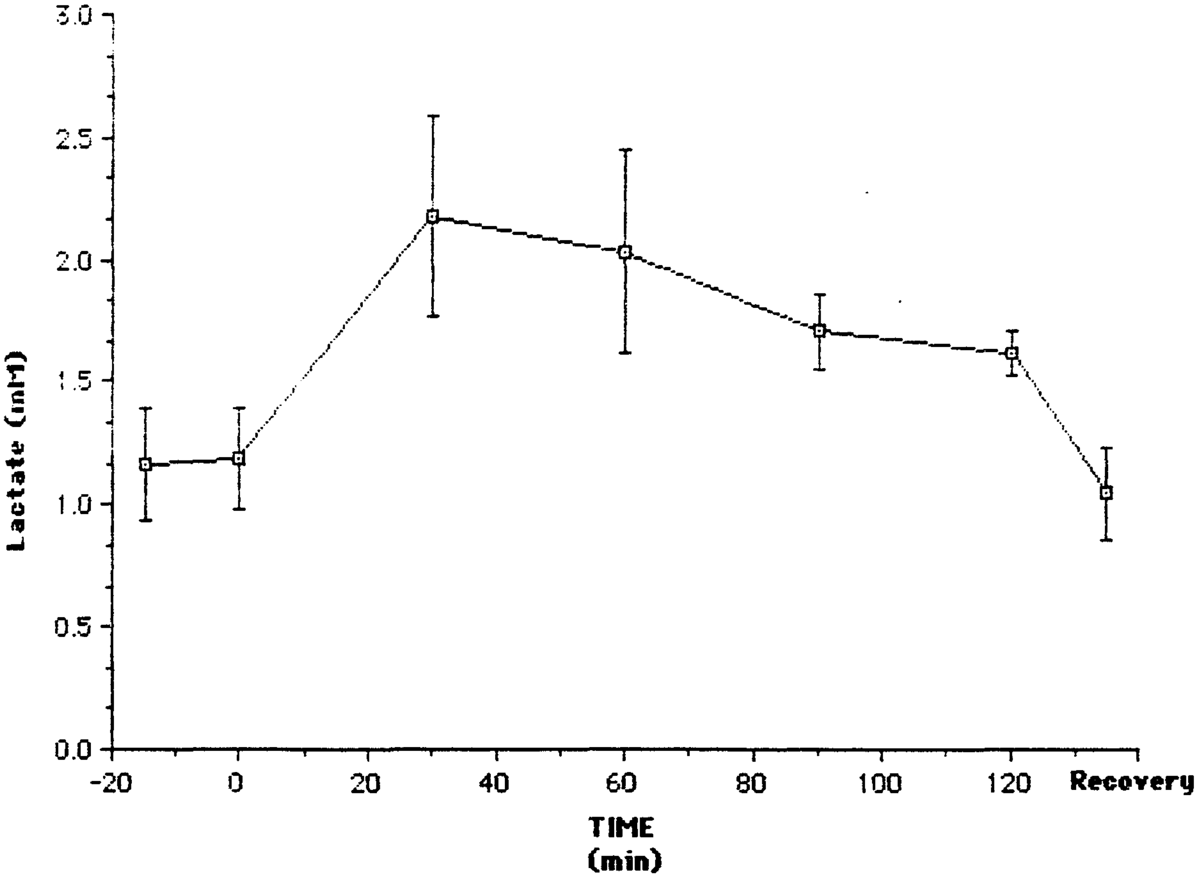

Figure 11. Changes in lactate over time (n=5).

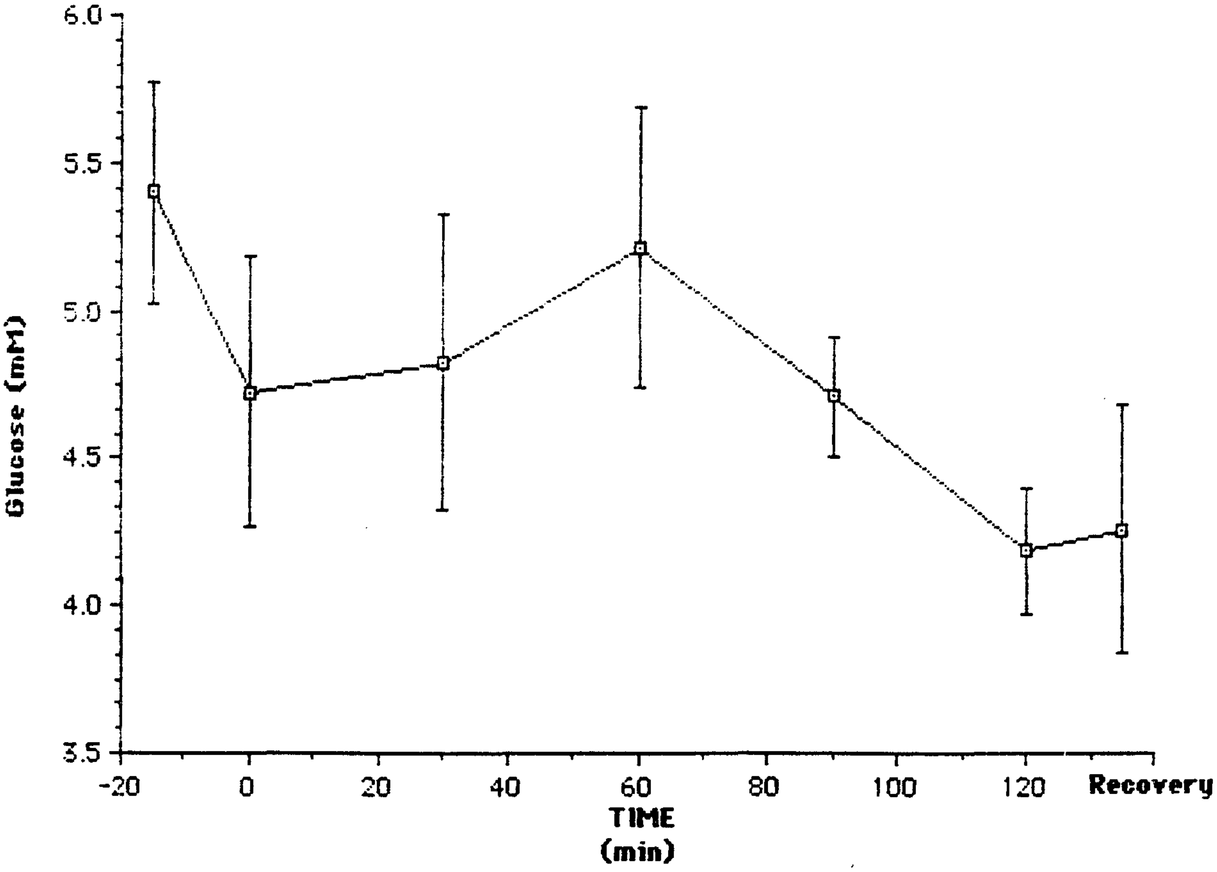

Figure 12. Changes in glucose over time (n=5).

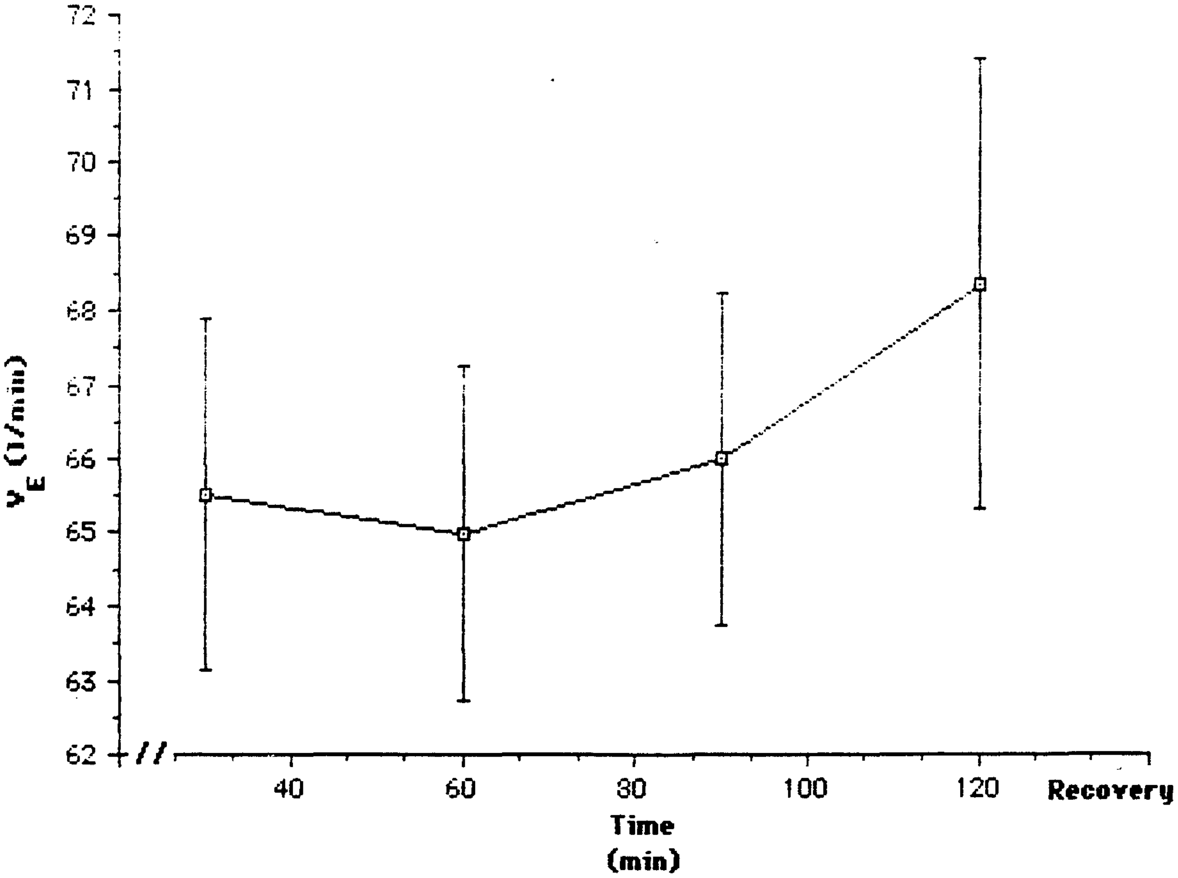

Figure 13. Changes in ventilation over time (n=12).

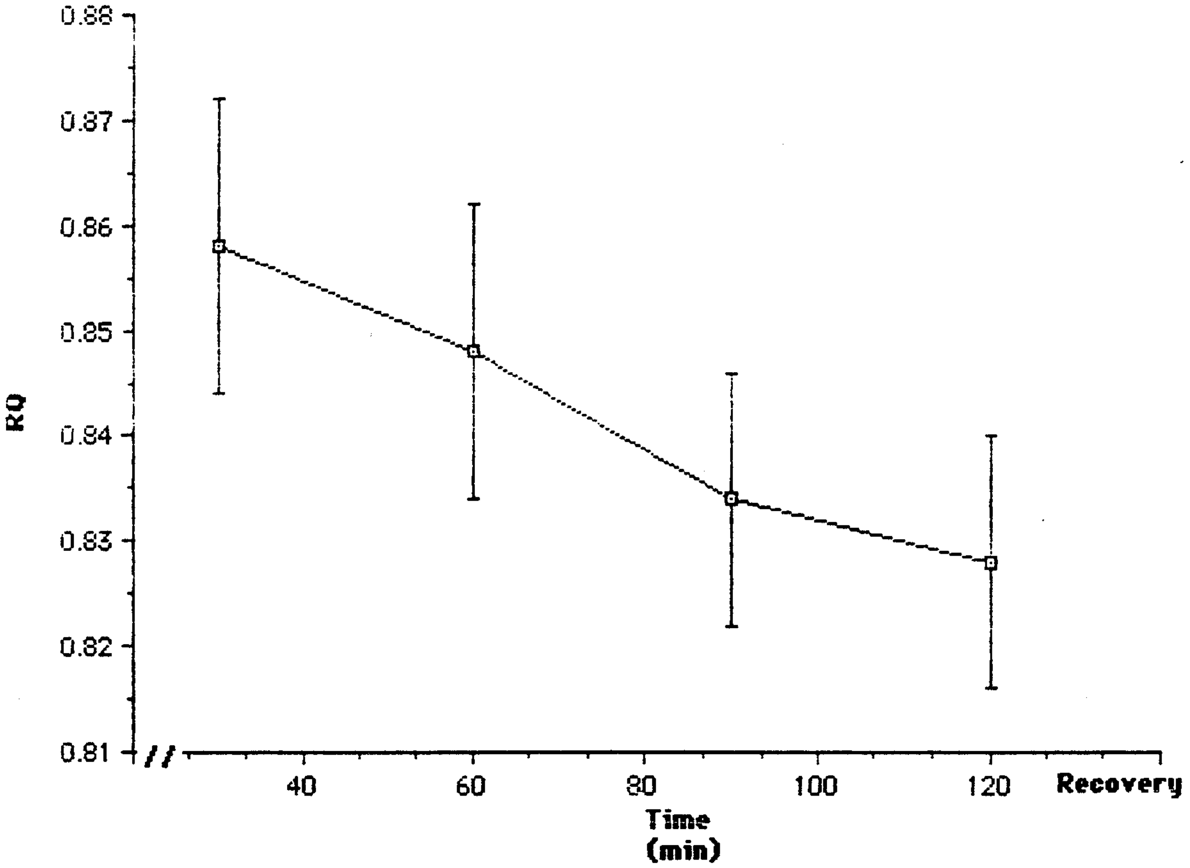

Figure 14. Changes in RQ over time
(n=12).

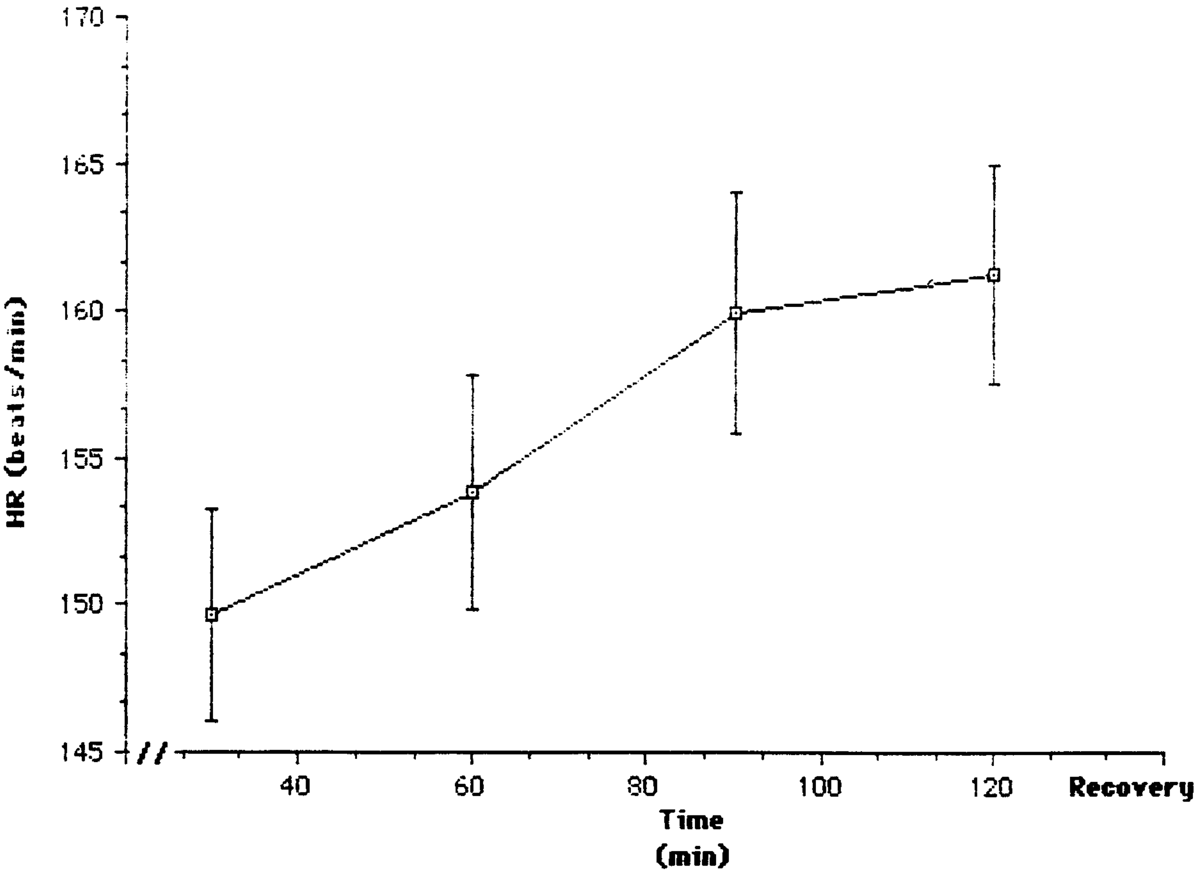

Figure 15. Changes in HR over time (n=12).

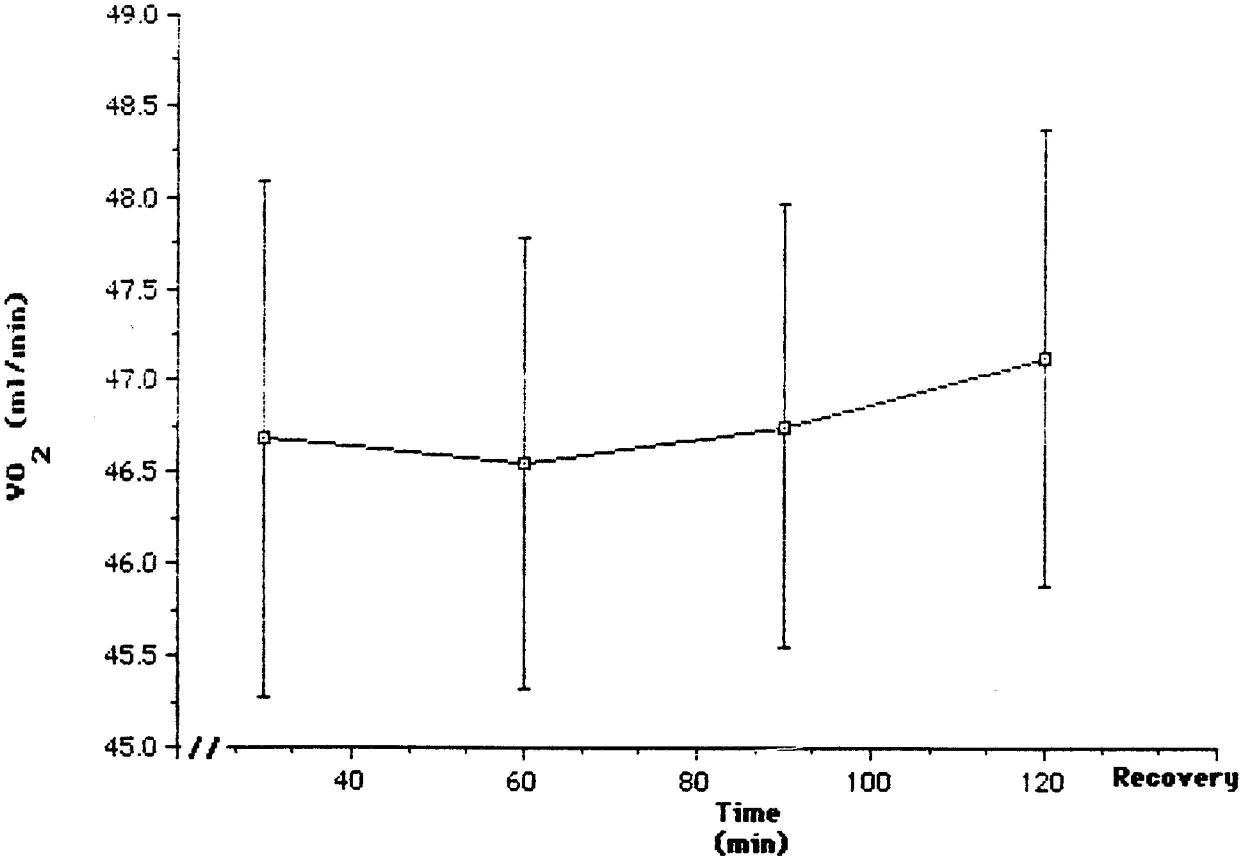

Figure 16. Changes in oxygen consumption over time (n=12).

RQ decreased significantly, *F*(3, 33) = 8.36, from Time 30 to Time 90 and Time 120. HR increased significantly, *F*(4, 44) = 362.85, with Time 30 significantly less than Time 120. VO_2 increased, but not significantly as exercise continued.

Relationships Among Variables

Pearson correlations were calculated among all variables at each time of assessment throughout the study. There were no significant correlations at Time -15. At Time 0, before the subjects began to run, a significant positive correlation was obtained between resting HR and resting Glu (r = .63)

Table 2 presents the significant relationships at Time 30. Higher lactate values were associated with higher TMD scores (more negative mood state; r = .66). Higher heart rates were associated with higher self-efficacy scores (r = .53) and subjects working at higher oxygen consumptions tended to score higher on TMD (r = .52) and have higher heart rates (r = .67).

Significant relationships at Time 60 are presented in Table 3. These relationships revealed that higher RPE ratings were associated with higher TMD scores (r = .70), lower self-efficacy scores (r = -.55), higher ventilation values (r = .54), and lower RQ values (r = -.60). In addition, TMD scores were related to self-efficacy scores (r = -.69), RQ scores (r = -.58) and VO_2 values (r = .55).

Table 2

Pearson Correlations at Time 30

	La30	HR30	$VO_2$30
TMD30	.66 (n=11)		.52 (n=12)
Se-Ef30		.53 (n=12)	
HR30			.67 (n=12)

Table 3

Pearson Correlations at Time 60

	RPE60	Se-Ef60	V_E60	RQ60	$VO_2$60
TMD60	.70 (n=12)	-.69 (n=12)		-.58 (n=12)	.55 (n=12)
RPE60		-.55 (n=12)	.54 (n=12)	-.60 (n=12)	
La60				-.56 (n=9)	
Se-Ef60				.67 (n=12)	
HR60					.62 (n=12)

Higher RQ values were also associated with lower lactate values (r = -.56) and higher self-efficacy scores (r = .67). Lastly, higher heart rates were associated with higher oxygen consumptions (r = .62).

Relationships among variables at Time 90 are presented in Table 4. These relationships revealed that TMD scores were associated with RPE ratings (r = .73), lower Glu values (r = -.53), lower self-efficacy ratings (r = -.81), and lower RQ scores (r = -.73). Higher RPE scores were associated with lower Glu values (r = -.52), lower self-efficacy scores (r = -.71), higher values for V_E (r = .59), and lower RQ values (r = -.74). In addition, RQ values were related to Glu values (r = .58) and self-efficacy scores (r = .79). Self-efficacy was also positively related to La (r = .63) and Glu (r = .67). And again, higher heart rates were associated with higher oxygen consumptions (r = .53).

Table 5 presents the significant correlations among variables at Time 120. At Time 120 higher TMD scores were associated with higher RPE scores (r = .75), lower self-efficacy scores (r = -.58), and higher values for V_E (r = .55) and VO_2 (r = .57). Higher RPE rating were also associated with lower self-efficacy rating (r = -.54), lower RQ values (r = -.67) and higher V_E values (r = .50). Self-efficacy was positively related to La (r = .81) and Glu (r = .78). La and Glu were positively related

Table 4

Pearson Correlations at Time 90

	RPE90	Glu90	Se-Ef90	V_E90	RQ90	$VO_2$90
TMD90	.73 (n=12)	-.53 (n=11)	-.81 (n=12)		-.73 (n=12)	
RPE90		-.52 (n=11)	-.71 (n=12)	.59 (n=12)	-.74 (n=12)	
La90			.63 (n=11)			
Glu90			.67 (n=11)		.58 (n=11)	
Se-Ef90					.79 (n=12)	
HR90						.53 (n=12)

Table 5

Pearson Correlations at Time 120

	RPE120	Glu120	Se-Ef120	V_E120	RQ120	$VO_2$120
TMD120	.75 (n=12)		-.58 (n=12)	.55 (n=12)		.57 (n=12)
RPE120			-.54 (n=12)	.50 (n=12)	-.67 (n=12)	
La120		.62 (n=12)	.81 (n=12)		.50 (n=12)	
Glu120			.78 (n=12)			
Se-Ef120					.56 (n=12)	
HR120					.56 (n=12)	
V_E120						.57 (n=12)

(r = .62) as was La and RQ (r = .50). RQ values were also correlated with self-efficacy scores (r = .56) and heart rates (r = .56). Lastly, VO_2 values correlated with V_E values (r = .57).

At recovery higher TMD scores were associated with lower self-efficacy ratings (r = -.58). In addition, La and Glu were positively related (r = .54).

To determine which combination of variables contribute the most to the cognitive appraisals of mood, self-efficacy and physical effort, separate step-wise regression equations were developed for each cognitive appraisal at each assessment time (Table 6). At Time 30 the cognitive appraisal of TMD was significantly predicted, multiple R=.816; F(2,8) = 7.98, by La and RQ. Runners at Time 30 who had lower RQ values and higher La values had a more negative mood score (higher TMD score). At Time 90 self-efficacy was significantly predicted, multiple R =.951; F(3, 7) = 21.90, by TMD, La and Glu. Higher self-efficacy scores could be predicted by lower TMD scores and higher La and Glu levels. At Time 120 RPE was significantly predicted, multiple R = .878; F (2, 9) = 15.13, by TMD and RQ. Those runners whose RPE was higher at Time 120 had a more negative mood (higher TMD scores) and lower RQ scores. Also at Time 120 self-efficacy was significantly predicted, multiple R = .923; F (2, 9) = 25.90, by La and TMD. Higher self-efficacy scores could be predicted by higher La

Table 6

Results of Regression Analyses Performed for Cognitive Appraisals

Cog. App. (Time)	Predictor	Beta	Multiple R	R squ
RPE (120)	TMD	.60		
	RQ	-.48	.88	.77

TMD (30)	La	.70		
	RQ	-.48	.81	.67
TMD (rec)	Self-eff	-.84		
	La	.58	.79	.62

Self-eff (90)	TMD	-.50		
	La	.43		
	Glu	.34	.95	.90
Self-eff (120)	La	.73		
	TMD	-.44	.92	.85
Self-eff (rec)	TMD	-.72		
	La	.59	.82	.68

values and lower TMD scores (better mood). Self-efficacy was also significantly predicted, multiple R = .822; F(2, 9) = 9.40, at recovery by TMD and La. At recovery those runners with higher self-efficacy ratings had lower TMD scores and higher La values. Also at recovery TMD was significantly predicted, multiple R = .788; F(2, 9) = 7.36, by self-efficacy and La. Those runners with better mood (lower TMD scores) had higher self-efficacy ratings and lower La values at recovery.

Summary of Results

Repeated measures ANOVAs revealed significant decreases in RQ, La, and Glu while V_E and HR increased significantly. The cognitive appraisals of self-efficacy and RPE decreased and increased, respectively. TMD demonstrated a significant change toward a more negative mood state. The moods of vigor and tension decreased while fatigue and depression increased during the two-hour run. Pearson correlations revealed that generally stronger relationships occurred among cognitive appraisals than between cognitive appraisals and metabolic indices. Step-wise regressions supported the cognitive appraisal-metabolic indice associations.

CHAPTER IV

DISCUSSION

This chapter discusses the results which have been presented. The observed changes in metabolic indices and cognitive appraisals are discussed first. Then the discussion shifts to the relationships among variables throughout the two-hour run. Finally, a summary is presented.

Changes in Metabolic Indices

All metabolic indices assessed for this study demonstrated the hypothesized changes. As subjects continued to exercise HR and V_E increased, La decreased slightly, and Glu and RQ decreased.

As exercise continued, La decreased slightly and RQ decreased indicating either glycogen depletion or greater lipid utilization. Carbohydrate depletion was also indicated by a drop in plasma Glu levels. Pruett (1970), Ahlborg et al. (1974), and Ahlborg and Felig (1982) have demonstrated Glu concentrations fall progressively during endurance exercise lasting longer than 60 minutes. These runners, who ran at close to 70% of maximal oxygen consumption, seem to have depleted muscle and liver glycogen stores and demonstrated a drop in plasma glucose concentrations. However, none of the twelve subjects exhibited hypoglycemia (plasma glucose less than 2.5 mmol/l).

Heart rate and V_E also rose as exercise continued. The increases in HR may have been due to dehydration and the cardiovascular system's attempt to transport oxygen and metabolic substrates to all organs and at the same time provide adequate blood flow from the body's core to the surface to minimize thermogenic stress. Ventilation increases during long-term work have been documented (Hansond et al., 1982; Thompson et al., 1974). The runners in this study demonstrated similar V_E increases possibly due to neurogenic factors, chemical stimuli, or chemoreceptors and pressoreceptors.

Changes in Cognitive Appraisals

The changes which occurred in RPE over time could be predicted by the research relating RPE to local and central physiological factors. As more physical stress is endured and physiological states are altered, an individual's subjective rating of effort expenditure should also change. Reseachers using a similar protocol investigating glucose feeding responses have demonstrated increases in RPE as exercise continues (Murray, Paul, Seifert, Eddy, & Halaby, 1989; Coogan & Coyle, 1989).

Self-efficacy has not been researched using a protocol similar to the one used in this study. However, Bandura's model suggests a change in the cognitive appraisal of self-efficacy derived from the four sources of information. A runner's past experience would inform him/her that as running continues he/she will become fatigued. That runner has also seen others run (vicarious experience) for prolonged periods and become fatigued (not necessarily in this study). Information from physiological states, specific to running, could offer important information concerning an individual's ability to continue to run. This information would most likely lead to a decrease in self-efficacy ratings.

The changes in TMD reflected the changes in fatigue and vigor. TMD increased with time and decreased slightly at recovery. In addition, depression increased slighly. The changes in vigor and fatigue seem understandable and consistent with each other. As exercise continued the runners felt less vigorous and more fatigued. The changes in depression may have been related to the task, in that by volunteering for this study these runners felt obligated to continue to run. Thus, a helpless or hopeless feeling may have been associated with the task. Tension was the only mood which changed in the opposite direction of TMD. Thus, although TMD increased, tension decreased. Previous research on acute exercise has demonstrated support for decreases in state anxiety. These runners also decreased in state anxiety (tension) from Time 0 to recovery; however, anxiety for these runners may have been elevated at the beginning due to the unknown task of running on a treadmill for two hours with a catheter in one arm. These changes in mood have not been previously documented. These runners did not experience a euphoric state as predicted by the endorphin hypothesis. In addition, these runners did not experience an improved overall mood, although tension decreased. This increase in negative mood throughout the run may suggest that the improved mood experienced at the end of a run may be relative to the mood experienced during the latter stages of a long run. Thus, the runners did not experience an overall enhanced mood but simply a relative mood improvement at recovery. The generic task of running on a treadmill with a catheter inserted must once again be considered, although it is important to note that all subjects reported that the catheter itself had no effect on their responses.

Relationships among Variables

RPE was assessed at Time 30, 60, 90, and 120. As exercise continued the relationship of RPE to other variables became apparent. At Time 30 no variables were related to RPE. By Time 60 RPE was positively associated with TMD ($r = .70$), and this relationship continued through to Time 90 ($r = .73$) and Time 120 ($r = .75$). In addition, RPE was negatively related to self-efficacy at these same times of assessment ($r = -.55$; $r = -.71$; $r = -.54$). Those runners who rated their effort as high also tended to have more negative moods and rated themselves less efficacious. These relationships suggest that as exercise continues, RPE is moderately related to self-efficacy and highly related to mood state. Also, RPE was moderately related to the central factor V_E ($r = .54$; $r = .59$; $r = .50$) throughout the run and had a somewhat higher relationship to the local factor RQ ($r = -.60$; $r = -.74$; $r = -.67$). These relationships are consistent with the research previously reviewed, which found that local signals (RQ in this study) dominate the perception of effort at all exercise intensities while ventilatory cues become more prominant at the higher intensities. However, only at Time 90 did Glu values relate to RPE ($r = -.52$). It would seem that this relationship should also hold at Time 120. Possibly the thought of the end of the exercise had an effect on the runners RPE.

The only significant regression equation for RPE occurred at Time 120 when RPE was predicted by TMD and RQ when a large proportion of the variance (R squared = .81) in RPE was predicted by a metabolic index and another cognitive appraisal (TMD).

At Time 30 TMD was positively related to La and VO_2 ($r = .66$; $r = .52$), two metabolic indices. As the run continued a significant relationship between TMD and self-efficacy appeared at Times 60, 90, and 120 ($r = -.69$; $r = -.81$; $r = -.58$). And, the relationship of VO_2 with

TMD continued at Times 60 and 120 (r = .55; r = .57). A negative mood state was also related to Glu at Time 90 (r = -.53) and V_E at Time 120 (r = .55). At recovery TMD was related to self-efficacy (r = -.58). An overall view of the relationships across time suggests that as exercise starts (30 min) moods are related to physiological responses; however, as exercise continues (60, 90, 120 min) moods are related to cognitive appraisals as well as metabolic indices with the appraisals of RPE and self-efficacy having a stronger relationship than the indices of VO_2, V_E, RQ, and Glu.

Regression analyses indicated that La and RQ predicted TMD at Time 30, and that TMD was predicted by self-efficacy and La at recovery. Again, it seems that as exercise continues, associations among cognitive appraisals magnify while associations with metabolic indices are maintained.

Efficacy expectations at Time 30 were related to HR (r = .53). At Times 60, 90, and 120 self-efficacy was related to TMD and RPE as previously discussed. At these same times self-efficacy was also related to RQ (r = .67; r = .79; r = .56) and at Times 90 and 120 self-efficacy was related to La (r = ,63; r = .81) and Glu (r = .67; r = .78). These results again demonstrate the association of a cognitive appraisal with a metabolic index (HR) early during an exercise bout (30 min). And as exercise continues (60, 90, 120) the relationship of the cognitive appraisal of self-efficacy with RPE and TMD becomes apparent and relationships with other metabolic indices develop. At Times 60, 90, and 120 self-efficacy was related to La, Glu and RQ, while RPE was related to V_E and RQ; and TMD was related to RQ.

Regression equations demonstrated that self-efficacy was predicted by TMD and La at Time 90 (multiple R = .951), by La and TMD (multiple R = .923) at Time 120, and by TMD and La (multiple R = .822) at recovery. It is apparent that La and TMD, a metabolic index and a cognitive appraisal, are highly predictive of self-efficacy during running after 90 minutes. Thus, for these runners a high proportion of the variance in efficacy expectations after 90 minutes of running could be accounted for by mood state and La values.

Summary

For the runners in this study the cognitive appraisals assessed were highly correlated during the later stages (60, 90, 120 min) of the two-hour run. In addition, TMD and self-efficacy were related to the physiological variables of V_E and HR respectively at Time 30, while RPE did not significantly correlate with any of the variables assessed. As the run continued beyond 30 minutes the magnitude of the relationships among cognitive appraisals increased slightly. At the same time, relationships between specific cognitive appraisals and specific metabolic indices demonstrated similar slight increases. However, at each time of assessment, stronger relationships occurred among cognitive appraisals than between cognitive appraisals and metabolic indices. The only exception occurred at Time 120, when self-efficacy was more strongly correlated with the metabolic indices of La and Glu than with TMD or RPE.

Because of the small sample and the many correlations among the variables, multicollinearity may lead to distortions in the estimations of the regression coefficients. Nonetheless, the significant regressions demonstrated further the relationship among cognitive appraisals and metabolic indices. An example of this relationship is demonstrated by the most consistent predictors of self-efficacy at Times 90, 120 and recovery, TMD and La.

Bandura's theory of self-efficacy would predict relationships between cognitive appraisals and metabolic indices. In addition, past experiences would reinforce relationships among cognitive appraisals. The results of this investigation support self-efficacy theory. Also as running continues and physiological stress increases, the salience of this response increases. Thus the relationships between cognitive appraisals and metabolic indices would also increase as demonstrated by the results of this study.

This investigation presents descriptive results which add to the body of literature on self-efficacy, RPE and mood during exercise, although it must be reinforced that the subjects in this study were well-trained, competitive distance runners, who were running on a treadmill (6 of the 12 for the first time) for two hours with a catheter in one arm. In an attempt to assess the ecological validity, the subjects were asked three questions at the end of the study: (a) How was this run similar/different to a training run/race? (b) Would your responses have been similar if you had been racing or on a training run? (c) Were your responses to the questionnaires affected by your previous responses to the same questions?

The runners responded to the first question by stating that this run on the treadmill was quite different than a race in that the effort was not as intense. In addition, the run was also dissimilar to a training run because of the lack of scenery, conversation and inability to vary pace. However, the runners stated, in response to question two, that their responses would have been similar if they had been on a training run because during a race they become much more "psyched up" and have a different mental focus. One runner stated that he probably would have been more "psychologically uplifted" after a training run. Two subjects stated that they never thought about these cognitive appraisals while running so they were not sure what their responses might be in another environment. Additionally, these subjects responses on the self-efficacy measures, RPE and POMS did affect their subsequent responses to the same measures. Subjects stated that they could recall approximatly 60.56 % of their previous responses.

Further research in this area using a greater number of subjects, different populations and varying environments (natural settings, competitive environments, lab set ups, etc. . . .) could offer further information into the mechanisms responsible for mood shifts, changes in efficacy expectations and interpretations of exertion. Mechanisms can also be examined by manipulating a variable and observing changes in relationships. In addition, the inclusion of other variables responsible for other functions in the body, for example catecholamines and endorphins, may lead to further insight into the cognitive appraisal-physiology relationship. Furthermore, these relationships can not be viewed as unidirectional but interactional in process. This study merely presents a picture of the relationships among three cognitive appraisals and several metabolic indices.

BIBLIOGRAPHY

Adolph, E.F. (1947). Physiology of man in the desert. New York: Interscience, Inc.

Ahlborg, G., & Felig, P. (1982). Lactate and glucose exchange across the forearm, legs and splanchnic bed during and after prolonged exercise. Journal of Clinical Investigation, 69, 45-54.

Ahlborg, G., Felig, P., Hagenfeldt, L., Hendler, R., & Wahren, J. (1974). Substrate turnover during prolonged exercise in man: Splanchnic and leg metabolism of glucose, free fatty acids, and amino acids. Journal of Clinical Investigation, 53, 1080-1090.

Albert, I., & Williams, M.H. (1975). Effects of post-hypnotic suggestions on muscular endurance. Perceptual and Motor Skills, 40, 131-139.

Allen, P.D., & Pandolf, K.B. (1977) Perceived exertion associated with breathing hyperoxic mixtures during submaximal work. Medicine and Science in Sports, 9, 122-127.

Astrand, P-O., Hallback, I., Hedman, R., & Saltin, B. (1963). Blood lactates after prolonged severe exercise. Journal of Applied Physiology, 18, 619.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Reviews, 84, 191-215.

Bandura, A. (1982). Self-efficacy in human agency. American Psychologist, 37, 122-147.

Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Englewood, N.J.: Prentice-Hall.

Bandura, A., Adams, N.E., Hardy, A.B., & Howells, G.N. (1980). Tests of the generality of self-efficacy theory. Journal of Personality and Social Psychology, 4, 39-66.

Bandura, A., & Cervone, D., Self-evaluative and self-efficacy mechanisms governing the motivational effects of goal systems. *Journal of Personality and Social Psycholology*, *45*, 1017-1028.

Berger, B.G. (1984). Running away from anxiety and depression: A female as well as male race. In M.L. Sachs & G.W. Buffone (Eds.), *Running as therapy: An integrated approach*. Lincoln: University of Nebraska.

Biran, M., & Wilson, G.T. (1981). Treatment of phobic disorders using cognitive and exposure methods: A self-efficacy analysis. *Journal of Counseling and Clinical Psychology*, *49*, 886-899.

Bird, A., & Brame, J.M. (1978). Self versus team attribution: A test of the "I'm OK, but the team's so-so" phenomenon. *Research Quarterly*, *49*, 260-267.

Black, J., Chesher, G.B., & Stammer, G.A. (1979). The painlessness of the long distance runner. *Medical Journal of Australia*., *1*, 522-523.

Borg, G.A.V. (1962). *Physical performance and perceived exertion*. Lund, Sweden: Gleerup.

Borg, G. (1970). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilatative Medicine*, *2*, 92-98.

Bradley, G. (1978). Self-serving baises in the attribution process: A reexamination of the fact or fiction question. *Journal of Personality and Social Psychology*., *36*,56-71.

Brown, I., Jr., & Inouye, D.K. (1978). Learned helplessness through modeling: The role of perceived similarity in competence. *Journal of Personality and Social Psychology*, *36*, 900-908.

Brown, R.S., Ramirez, D.E., & Taub, J.M. (1978). The perscription of exercise for depression. *The Physician and Sportsmedicine*, *1*, 34-45.

Brunner, B.C. (1969). Personality and motivating factors influencing adult participation in vigorous physical activity, *Research Quarterly*, *40*, 464-469.

Buffone, G.W. (1984). Running and depression. In M.L. Sachs & G.W. Buffone (Eds.), *Running as therapy: An integrated approach*. Lincoln: University of Nebraska Press.

Cadarett, B.S., Hoffman, J.W., Caudill, M., Kutz, I., Levine, L., Benson, H., & Goldman, R. F. (1982). Effects of the relaxation response on selected cardiorespiratory responses during physical exercise. Medicine and Science of Sports and Exercise, 14, 117.

Cafarelli, E. (1982). Peripheral and central inputs to the effort sense during cycling exercise. Medicine Science in Sports and Exercise, 14, 382-389.

Carver, C.S., Coleman, A.E., & Glass, D.C. (1976). The coronary-prone behavior pattern and the suppression of fatigue on a treadmill test. Journal of Personality and Social Psychology, 33, 460-466.

Coogan, A.R., & Coyle, E.F. (1989). Metabolism and performance following carbohydrate ingestion late in exercise. Medicine and Science of Sports and Exercise, 21, 59-65.

Corbin, C.B., Laurie, D.R., Gruger, C., & Smiley, B. (1984). Vicarious success experience as a factor influencing self-confidence, attitudes and physical activity of adult women. Journal Teaching Physical Education, 4, 17-23.

Davies, C.T.M., & Sargeant, A. J. (1979). The effects of atropine and practolol on the perception of exertion during treadmill exercise. Ergonomics, 22, 1141-1146.

Desharnais, R., Bouillon, J., & Godin, G. (1986). Self-efficacy and outcome expectations as determinants of exercise adherance. Psycholological Reports, 59, 1155-1159.

Dill, D.B., & Costill, D.L. (1974). Calculation of percentage changes in volume of blood, plasma, and red cells in dehydration. Journal of Applied Physiology, 37, 247-248.

Dishman, R.K. (1985). Medical psycholoy in exercise and sport. Medical Clinics of North America, 69, 123-143.

Docktor, R., & Sharkey, B. J. (1971). Note on some physiological and subjective reactions to exercise and training. Perceptual and Motor Skills, 32, 233-234.

Edwards, R.H.T., Melcher, A., Hesser, C. M.,Wegertz, O., & Ekelund, L. G. (1972). Physiological correlates of perceived exertion in continuous and intermittent exercise with the same average power output. European Journal of Clinical Investigation, 2, 108-114.

Ekblom, B., & Goldbarg, A. N. (1971). The influence of training and other factors on the subjective rating of perceived exertion. Acta Physiologica Scandinavia, 83, 399-406.

Ewart, C.K., Taylor, C.B., Reese, L.B., & DeBusk, R.F. (1983). Effects of early postmyocardial infarction exercise testing on self-perception and subsequent physical activity. American Journal of Cardiology, 51, 1076-1080.

Farrell, P.A., Gates, W. K., Maksud, M. G., & Morgan, W. P. (1982). Increases in plasma b-endorphin/b-lipotropin immunoreactivity after treadmill running in humans. Journal of Applied Physiology, 52, 1245-1249.

Feltz, D.L. (1988). Self-confidence and sports performance. In K. Pandolf (ed.), Exercise and Sport Science Reviews (Vol. 16, pp.423-457). N.Y.: MacMillan Publishing Company.

Feltz, D.L. (1982). Path analysis of the causal elements in Bandura's theory of self-fficacy and an anxiety-based model of avoidance behavior. Journal of Personality and Social Psychology, 42, 764-781.

Feltz, D.L., Landers, D.M., & Raeder, U. (1979). Enhancing self-efficacy in high avoidance motor tasks: A comparison of modeling techniques. Journal of Sport Psychology, 1, 112-122.

Feltz, D.L., & Mugno, D.A. (1983). A replication of the path analysis of the causal elements in Bandura's theory of self-efficacy and the influence of autonomic perception. Journal of Sport Psychology, 5, 263-277.

Folkins, C.H., & Sime, W.E. (1981). Physical fitness training and mental health. American Psychologist, 36, 373-389.

Forsyth, D.R., & Schlenker, B. R. (1979). Attributional egocentrism following performance of an competitive task. Journal of Social Psychology, 102, 215-222.

Frankenhaeuser, M., Post, B., Nordheden, B., & Sjoeberg, H. (1969). Physiological and subjective reactions to different physical work loads. Perceptual and Motor Skills, 28, 343-349.

Gamberale, F. (1972). Perceived exertion, heart rate, oxygen uptake and blood lactate in different work operations. Ergonomics, 15, 545-554.

Gollnick, P.D., Armstrong, R.B., Sembrowich, W.L., & Saltin, B. (1973). Glycogen depletion pattern in human skeletal muscle fibers after heavy exercise. Journal of Applied Physiology, 34, 615.

Gould, D., & Weiss, M. (1981). Effect of model similarity and model self-talk on self-efficacy in muscular endurance. Journal of Sport Psychology, 3, 17-29.

Haier, R.J., Quaid, K., & Mills, J.S.C. (1981). Naloxone alters pain perception after jogging. Psychiatry Research, 5, 231-232.

Hanson, P., Claremont, A., Dempsey, J.A., & Reddan, W. (1982). Determinants and consequences of ventilatory responses to competitive endurance running. Journal of Applied Physiology, 52, 615-623.

Henriksson, J., Knuttgen, H. G., & Bonde-Petersen, F. (1972). Perceived exertion during exercise with concentric and eccentric muscle contractions. Ergonomics, 15, 537-544.

Hermansen, L., Hultman, E., & Saltin, B. (1967). Muscle glycogen during prolonged severe exercise. Acta Physiologica Scandinavica, 71, 129-139.

Hermansen, L., Pruett, E.D.R., Osnes, J.B., & Giere, F.A. (1970). Blood glucose and plasma insulin in response to maximal exercise and glucoce infusion. Journal of Applied Physiology, 29, 13.

Hickson, R.C., Hagberg, J.M., Conlee, R.K., & Jones, D.A., Ehsani, A.A., & Winder, W.W. (1979). Effect of training on hormonal responses to exercise in competitive swimmers. European Journal of Applied Physiology, 41, 211-219.

Hogan, P.I., & J.P. Santomier. (1984). Effect of mastering swim skills on older adults' self-efficacy. Research Quarterly for Exercise and Sport, 55, 294-296

Horstman, D.H., Morgan, W. P., Cymerman, A., & Stokes, J. (1979). Perception of effort during constant work to self-imposed exhaustion. Perceptual and Motor Skills, 48, 1111-1126.

Issekutz, B., Shaw, W.A.S., & Issekutz, T.B. (1975). Effect of lactate on the FFA and glycerol turnover in resting and exercising dogs. Journal of Applied Physiology, 39, 349-353.

Jackson, A., Dishman, R. K., La Croix, S., Patton, R., & Weinberg, R. (1981). The heart rate, perceived exertion, and pace of the 1.5 mile run. Medicine and Science in Sports and Exercise, 13, 13:224-228.

Jorfeldt, L. (1970). Metabolism of L()- lactate in human skeletal muscle during exercise. Acta Physiologica Scandanavica, 78, (Supplementum 338), 1-67.

Jorfeldt, L., Juhlin-Dunnfelt, A., & Karlson, J. (1978). Lactate release in relation to tissue lactate in human skeletal muscle during exercise. Journal of Applied Physiology, 44, 350-352.

Koyal, S.N., Whipp, B.J., Huntsman, D., Bray, G.A., & Wasserman, K. (1976). Ventilatory respomses to the metabolic acidosis of treadmill and cycle ergometry. Journal of Applied Physiology, 40, 864-867.

Kaplan, R.M., Atkins, C.J., & Reinsch, S. (1984). Specific efrficacy expectations mediate exercise compliance in patients with COPD. Health Psychology, 3, 223-242.

Kavanagh, D., & Hausfeld, S. (1986). Physical performance and self-efficacy under happy and sad moods. Journal of Sport Psychology, 8, 112-123.

Kay, C., & Shephard, R. J. (1969). On muscle strength and the threshold of anaerobic work. Internationale Zeitschrift fur Angewandte Physiologie, 27, 311-328.

Kazdin, A.E. (1979). Imagery elaboration and self-efficacy in the covert modeling treatment of unassertive behavior. Journal of Consulting and Clinical Psychology, 47, 725-733.

Krall, L.P. (1978). Joslin diabetes manual. Philadelphia: Lea & Febiger.

Levine, S.A., Gordon, B., & Derick, C.L. (1924). Some changes in the chemical constituents of the blood following a marathon race; with special reference to the development of hypoglycemia. Journal of the American Medical Association, 82, 1778-1779.

Lollgen H., Graham, T., & Sjogaard, G. (1980). Muscle metabolites, force, and perceived exertion bicycling at varying pedal rates. Medicine and Science in Sports and Exercise, 12, 345-361.

Lollgen, H., Ulmer, H.V., Gross, R., Wilbert, G., & Nieding, G. (1975). Methodological aspects of preceived exertion rating and its relationship to pedalling rate and rotating mass. European Journal of Applied Physiology, 34, 205-215.

Martin, G.J. (1981). Effect of sleep deprivation on tolerance of prolonged exercise. European Journal of Applied Physiology, 47, 345-354.

Martin, B.J., & Gaddis, G.M. (1981). Exercise after sleep deprivation. Medicine and Science in Sports and Exercise, 13, 220-223.

McAuley, E. (1985). Modeling and self-efficacy: A test of Bandura's model. Journal of Sport Psychology, 7, 283-295.

McMurray, R.G., Forsythe, W.A., Mar, M.H., & Hardy, C.J. (1987). Exercise intensity-related responses of B-endorphins and catecholamines. Medicine and Science in Sports and Exercise, 13, 150-163

McNair, D.M., Lorr, M., & Droppleman, L.F. (1971). Profile of mood states manual. San Diego, CA: Educational and Industrial Testing Service.

Mihevic, P.M. (1981). Sensory cues for perceived exertion: A review. Medicine and Science in Sports and Exercise, 13, 150-163.

Mihevic, P.M., Gliner, J.A., & Horvath, S.M. (1981). Perception of effort and respiratory sensitivity during exposure to ozone. Ergonomics., 24, 365-374.

Morgan, W.P. (1973). Psychological factors influencing perceived exertion. Medicine and Science in Sports., 5, 97-103.

Morgan, W.P. (1981). Psychophysiology of self-awareness during vigorous physical activity. Research Quarterly for Exercise and Sport, 52, 385-427.

Morgan, W.P., & Borg, G. (1980). Perception of effort in the prescription of physical activity. In: Mental health and emotional aspects of sports.. T. Craig (Ed.) Chicago: American Medical Association.

Morgan W.P., Hirota, K., Weitz, G.A., & Balke, B. (1976).

Hypnotic perturbation of perceived exertion: Ventilatory consequences. American Journal of Clinical Hypnosis, 189, 182-190.

Morgan, W.P., Horstman, D.H., Cymerman, A., & Stokes, J. (1983) Facilitation of physical performance by means of a cognitive strategy. Cognitive Therapy and. Research, 7, 251-264.

Morgan, W.P., & Pollock, M.L. (1977). Psychologic characterization of the elite distance runner. Annals of the New York Academy of Science, 301, 382-403.

Morgan, W.P., Roberts, J.A., Brand, F.R., & Feinerman, A.D. (1970). Psychological effect of chronic physical activity. Medicine and Science in Sport, 2, 213-217.

Morgan, W.P., Roberts, J.A., & Feinerman, A.D. (1971). Psychologic effect of acute physical activity. Archives of Physical Medicine and Rehabilitation, 52, 422-425.

Murray, R., Paul, G.L., Seifert, J.G., Eddy, D.E., & Halaby, G.A. (1989). The effects of glucose, fructose, and sucrose ingestion during exercise. Medicine and Science in Sport, 21, 275-282.

Owen, O.E., Morgan, A.P., Kemp, H.G., Sullivan, J.M., Herrera, M.G., & Cahill, G.F. (1967). Brain metabolism during fasting. Journal of Clinical Investigation, 46, 1589-1595.

Pandolf, K.B. (1978). Influence of local and central factors in dominating rated perceived exertion during physical work. Perceptual and Motor Skills., 46, 683-698.

Pandolf, K.B., Burse, R. L., & Goldman, R. F. (1975). Differentiated ratings of perceived exertion during physical conditioning of older individuals using leg-weight loading. Perceptual and Motor Skills., 40, 563-574.

Pandolf,K.B., Cafarelli, E., Noble, B. J., & Metz, K. F. (1972). Perceptual responses during prolonged work. Perceptual and Motor Skills, 35, 975-985.

Pandolf, K.B., & Noble, B.J. (1973). The effect of pedalling speed and resistance changs on perceived exertion for equivalent power outputs on the bicycle ergometer. Medicine and Science in Sports, 5, 132-136.

Pedersen, P.K., & Welch, G.H. (1977). Oxygen breathing, selected physiological variables and perception of effort during submaximal exercise. In G. Borg (ed.), Physical work and effort. Oxford: Pergamon Press, Inc.

Pruett, E.D.R. (1970). Glucose and insulin during prolonged work stress in men living on different diets. Journal of Applied Physiology, 28, 199-208.

Rejeski, J.W. (1981). The perception of exertion: A social psychophysiological intergration. Journal of Sport Psychology, 4, 305-320.

Richter, E.A., Sonne, B., Christensen, N.J., & Galbo, H. (1981). Role of epinephrine for muscular glycogenolysis and pancreatic hormonal secretion in running rats. American Journal of Physiology, 240, 526-532.

Robertson, R.J. (1981). The perception of exertion: A social psychophysiological integration. Medicine and Science in Sports and Exercise, 4, 305-320.

Rotter, J.B. (1954). Social learning and clinical psychology. Englewood Cliffs, N.J.: Prentice-Hall.

Rowell, L.B. (1974). Human cardiovascular adjustments to exercise and thermal stress. Physiological Reviews, 54, 75-159.

Rowell, L.B., Marx, H.J., Bruce, R.A., Conn, R.D., & Kusumi, F. (1966). Reductions in cardiac output, central blood volume, and stroke volume with thermal stress in normal men during exercise. Journal of Clinical Investigation, 45, 1801.

Sargeant, A.J., & Davies, T. C. M. (1973). Perceived exertion during rhythmic exercise involving different muscle masses. Journal Human Ergology, 2, 3-11.

Scanlan, T.K., & Passer, M. W. (1980). Self-serving biases in the competitive sport setting: An attributional dilemma. Journal of Sport Psychology, 2, 124-236.

Sigma Chemical Company. (1987). Sigma Pyruvate/Lactate Kit, St. Louis, MO.

Sigma Chemical Company. (1986). Sigma Glucose Kit, St. Louis, MO.

Sime, W.E. (1977). A comparison of exercise and meditation in reducing physiological response to stress. Medicine and Science in Sports, 9, 55.

Simmons, D.H., Alpas, A.P., Tashkin, D.P., & Coulson, A. (1978). Hyperlactatemia due to arterial hypoxemia or reduced cardiac output or both. Journal of Applied Physiology, 45, 195-202.

Simonson, E. (1971). Regulation of respiration in work and fatigue. In E. Simonson (Ed.), Physiology of work capacity and fatigue. Springfield, IL: Charles C. Thomas Publisher.

Sjoderg, H., Frankenhaeuser, M., & Bjurstedt, H. (1979). Interactions between heart rate, psychomotor performance and perceived effort during physical work as influenced by beta-adrenergic blockage. Biological Psychology, 8, 31-43.

Spink, K.S. (1978). Win-loss causal attribuations of high school basketball players. Canadian Journal of Applied Sports Science, 3, 195-200.

Squires, R.W., Rod, J.L., Pollock, M.L., & Foster, C. (1982). Effect of propranolol on perceived exertion soon after myocardial revascularization surgery. Medicine and Science in Sports and Exercise, 14, 276-280.

Taylor, C.B., Bandura, A., Ewart, C.K., Miller, N.H., & Debusk, R.F. (1985). Raising spouse's ans patient's perceptions of his cardiac capabilities following a myocardial infarction. American Journal of Cardiology, 55, 635-638.

Thompson, J.M., Dempsey, J.A., Chosy, L.W., Shahidi, N.T., & Reddan, W.G. (1974). Oxygen transport and oxyhemoglobin dissociation during prolonged muscular work. Journal of Applied Physiology, 37, 658-664.

Wahren, J., Felig, P., Ahlborg, G., & Jorfeldt, L. (1971). Glucose Metabolism during leg exercise in man. Journal of Clinical Investigation, 50, 2715-2725.

Weinberg, R. (1986). Relationship between self-efficacy and cognitive strategies in enhancing endurance performance. International Journal of Sport Psychology, 17, 280-293.

Weinberg, R., Gould, D., & Jackson, A. (1979). Expectations and performance: An empirical test of Bandura's self-efficacy theory. Journal of Sport Psychology, 1, 320-331.

Weinberg, R.S., Gould, D., Yukelson, D., & Jackson, A. (1981). The effect of preexisting and manipulated self-efficacy on a competitive muscular endurance task. Journal of Sport Psychology, 3, 345-354.

Weinberg, R.S., Sinardi, M., & Jackson, A. (1982). Effect of bar height and modeling on anxiety, self-confidence and gymnastic performance. International Gymnast, 2, 11-13.

Wilkes, R.L., & Summers, J.J. (1984). Cognitions, mediating variables, and strength performance. Journal of Sport Psychology, 6, 351-359.

Wurtele, S.K. (1986). Self-efficacy and athletic performance; A review. Journal of Social and Clinical Psychology, 4, 290-301.

Young, A.J., Cymerman, A., & Pandolf, K.B. (1982). Differentiated ratings of perceived exertion are influenced by high altitude exposure. Medicine and Science in Sports and Exercise, 14, , 223-228.

Appendix A

CONSENT FORM FOR HUMAN SUBJECTS

THE UNIVERSITY OF NORTH CAROLINA AT GREENSBORO
SCHOOL OF HEALTH, PHYSICAL EDUCATION RECREATION AND DANCE

Subject's Name:______________________

Project Title: Changes in Cognitive Appraisals and Metabolic Indices of Physical Exertion During A Two Hour Run

Project Supervisor: Dr. Diane L. Gill, Associate Professor

Project Coordinator: Edmund O. Acevedo, Graduate Assistant, Department of Physical Education

I understand that the purpose of this study is to investigate the physiological adaptations including heart rate, ventilation, respiratory quotient, plasma lactate, and plasma glucose during a two hour run. Also changes in the cognitive apraisals of exertion, expectations, and affect throughout an exhaustive endurance run will be assessed. And finally, this study will examine the relationships between these metabolic indices and cognitive appraisals.

I understand that during this study I will report to the Human Performance Laboratory (Stone 112) for at least 2 visits. During the first visit I will perform a maximal exercise stress test on a motorized treadmill. During this test electrodes will be attached to my torso so that cardiac responses to exercise may be monitored. Also ventilatory gases will be continuously monitored while breathing through a one-way mouth piece. I understand that during and/or after this test I may become dizzy, tired or weak as a result of fatigue. There is a rare possibility of heart attack (<3 in 10,000) or death (<1 in 10,000) as a result of the maximal exercise test, however the researchers will minimize such risk by using subjects between the ages of 18 and 40, by preliminary screening with a medical history form, and continuous monitoring throughout the test as specified by the American College of Sports Medicine Guidelines. I understand that the results from this test will be used to determine the intensity levels for the submaximal test.

I understand that within a week I will return to the lab. At this time I will run for two hours at 70 percent of my maximal oxygen consumption. I will enter the lab after an overnight fast. Upon entering the lab I will rest in the supine position while a catheter is inserted into my antecubital vein, located in the elbow region. The catheterization will be performed by a trained phlebotomist, Dr. Allan Goldfarb. The insertion of the catheter may be slightly painful, but that the pain will subside soon after insertion. There may be some bruising and bleeding associated with the use of a catheter and there is some risk of infection. However, the risk of bruising and bleeding will be minimized since direct pressure will be applied to the insertion sight after the catheter has been removed and until the bleeding stops. In addition, the risk of infection will be minimized since only sterile techniques will be used. To prevent clotting the catheter will be flushed periodically with "physiological saline" while it is inserted into my arm. After the catheter has been inserted I will complete a mood assessment and rest for 20 minutes in the supine position. Prior to beginning the run, electrodes will be attached and another affect measure will be completed. At 30, 60, 90, and 120 minutes ventilatory measures, affect assessments, expectations and an effort assessment will be taken. In addition, at the same time 6 milliliters of blood will be drawn into sterile syringes. At the end of the two hour run, a 20 minute seated recovery will begin after which another blood sample, expectations and moods will be assessed. The catheter will then be removed from my arm, and I will hold direct pressure on the insertion sight until the researchers confirm that the bleeding has stopped. CDC blood handling guidelines will be followed.

I confirm that my participation in this study is completely voluntary, and that no coercion of any kind has been used to obtain my cooperation. I also understand that I can withdraw my consent and terminate my participation in this study at any time without prejudice. I understand that all information obtained in this study will remain confidential and anonymous. I understand that a summary of the results of this study will be made available to me, upon my request, after the completion of this study.

I confirm that I have been informed of the procedures that will be used in this study. I understand what is required of me as a subject. I agree that any questions I have regarding this study and the procedures have been answered to my satisfaction. I give my voluntary cooperation as a participant.

Signature of Subject	Phone Number
Address	Date
	Witness

Appendix B

MEDICAL HISTORY
UNIVERSITY OF NORTH CAROLINA AT GREENSBORO
DEPARTMENT OF PHYSICAL EDUCATION
HUMAN PERFORMANCE LABORATORY

Name: ____________________ Date: ______

I, ____________________, hereby authorize the release of any aspect of my medical history which may be necessary for my participation in this project by the Department of Physical Education at the University of North Carolina at Greensboro.

. . . .

Please respond "Yes" or "No" to the following health data.

_____ 1. Heart attack, coronary bypass, or cardiac surgery

_____ 2. Chest discomfort - especially with exertion

_____ 3. High blood pressure

_____ 4. Extra, skipped or rapid heart beats/palpitations

_____ 5. Heart murmurs, clicks, or unusual cardiac findings

_____ 6. Rheumatic fever

_____ 7. Ankle swelling

_____ 8. Peripheral vascular disease

_____ 9. Phlebitis, emboli

_____ 10. Unusual shortness of breath

_____ 11. Lightheadedness or fainting

_____ 12. Pulmonary disease including asthma, emphysema and bronchitis

_____ 13. Abnormal blood lipids

_____ 14. Diabetes

_____ 15. Stroke

_____ 16. Emotional disorders

_____ 17. Medications of all types

_____ 18. Recent illness, hospitalization or surgical procedures

_____ 19. Orthopedic problems, arthritis

20. Family (granparents, parents, aunts, uncles, and siblings)

_____ Coronary disease

_____ Sudden death

_____ Congenital heart disease

21. Other habits

_____ Caffeine including cola drinks

_____ Alcohol

_____ Tobacco

_____ Other unusual habits or dieting

Exercise Information

Years of running experience _____

Number of miles averaged per week for the past month _____

Marathon personal best _____

10 Km personal best _____

If you have any other medical problems and/or current medications please list below.

____

adapted from Guidelines for Exercise Testing and Prescription (3rd ed.), Lea & Febiger, Philadelphia, PA. 1986.

Appendix C

NAME______________________ DATE_____

Below is a list of words that describe feelings people have. Please read each one carefully. Then fill in ONE circle under the answer to the right which best describes HOW YOU FEEL RIGHT AT THIS MOMENT.

The numbers refer to these phrases.
0 = Not at all
1 = A little
2 = Moderately
3 = Quite a bit
4 = Extremely

1. Tense 0 1 2 3 4
2. Angry 0 1 2 3 4
3. Worn out 0 1 2 3 4
4. Unhappy 0 1 2 3 4
5. Lively 0 1 2 3 4
6. Confused 0 1 2 3 4
7. Peeved 0 1 2 3 4
8. Sad 0 1 2 3 4
9. Active 0 1 2 3 4
10. On edge 0 1 2 3 4
11. Grouchy 0 1 2 3 4
12. Blue 0 1 2 3 4
13. Energetic 0 1 2 3 4
14. Hopeless 0 1 2 3 4
15. Uneasy 0 1 2 3 4
16. Restless 0 1 2 3 4
17. Unable to concentrate 0 1 2 3 4
18. Fatigued 0 1 2 3 4
19. Annoyed 0 1 2 3 4
20. Discouraged 0 1 2 3 4
21. Resentful 0 1 2 3 4
22. Nervous 0 1 2 3 4
23. Miserable 0 1 2 3 4
24. Cheerful 0 1 2 3 4
25. Bitter 0 1 2 3 4
26. Exhausted 0 1 2 3 4
27. Anxious 0 1 2 3 4
28. Helpless 0 1 2 3 4
29. Weary 0 1 2 3 4
30. Bewildered 0 1 2 3 4
31. Furious 0 1 2 3 4
32. Full of pep 0 1 2 3 4
33. Worthless 0 1 2 3 4
34. Forgetful 0 1 2 3 4
35. Vigorous 0 1 2 3 4
36. Uncertain about things 0 1 2 3 4
37. Bushed 0 1 2 3 4

Item Breakdown For POMS

Depression: unhappy, sad, blue, hopeless, discouraged, miserable, helpless, worthless.

Vigor: lively, active, energetic, cheerful, full of pep, vigorous.

Confusion: confused, unable to concentrate, bewildered, forgetful, uncertain about things.

Tension: tense, on edge, uneasy, restless, nervous, anxious.

Anger: angry, peeved, grouchy, annoyed, resentful, bitter, furious.

Fatigue: worn-out, fatigued, exhausted, weary, bushed.

Appendix D

Perceived Exertion

Instructions: Estimate how hard you feel the work is, including total inner feelings of exertion, combining all sensations and feelings of physical stress and effort.

6

7 VERY, VERY LIGHT

8

9 VERY LIGHT

10

11 FAIRLY LIGHT

12

13 SOMEWHAT HARD

14

15 HARD

16

17 VERY HARD

18

19 VERY, VERY HARD

20

Appendix E

Self-Efficacy Measure

Instructions: For each task below, indicate how confident or certain you are that you could complete that task.

Not at all certain — Absolutely certain

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

	Percent Certainty
I can run:	
30 seconds per mile slower for the next 30 minutes.	________
at the same speed for the next 30 minutes.	________
30 seconds per mile faster for the next 30 minutes.	________
1 minute per mile faster for the next 30 minutes.	________
1 min. 30 sec. per mile faster for the next 30 minutes.	________

Appendix F

Moods Data

	Dep.	Con.	Ten.	Angr.	Fatg.	Vigor
-15	.033	.283	1.015	.036	.500	1.792
	±.017	±.100	±.199	±.026	±.162	±.136
0	.011	.583	.918	.036	.283	1.903
	±.011	±.409	±.141	±.036	±.109	±.183
30	.189	.367	.623	.143	.533	2.083
	±.083	±.128	±.435	±.118	±.119	±.311
60	.303	.500	.500	.203	1.0	1.666
	±.165	±.168	±.082	±.114	±.232	±.358
90	.314	.564	.529	.252	1.583	1.556
	±.186	±.268	±.140	±.163	±.397	±.332
120	.273	.683	.570	.345	2.20	1.154
	±.107	±.242	±.163	±.179	±.219	±.294
Rec	.116	.456	.251	.107	2.017	.819
	±.055	±.219	±.142	±.095	±.269	±.226

Values ± SE.

RPE, Self-Efficacy and TMD Data

	RPE	Se-Ef	TMD
-15			.075 ±.348
0			-.071 ±.550
30	11.583 ±.379	336.667 ±18.436	-0.228 ±.566
60	12.417 ±.417	303.333 ±25.564	.839 ±.888
90	13.330 ±.497	286.667 ±30.008	1.689 ±1.134
120	14.330 ±.396	215.833 ±21.583	2.917 ±.880
Rec		220.0 ±26.94	2.123 ±.760

Values ± SE.

Lactate and Glucose Data

	La	Glu
-15	1.16 ±.23	5.4 ±.371
0	1.186 ±.201	4.726 ±.461
30	2.182 ±.409	4.826 ±.504
60	2.036 ±.412	5.214 ±.471
90	1.71 ±.154	4.708 ±.205
120	1.62 ±.087	4.188 ±.216
Rec	1.046 ±.187	4.260 ±.421

Values ± SE.

Corrected for changes in plasma volume.

Cardiorespiratory Data

	HR	V_E	VO_2	RQ
30	149.667	65.511	46.682	.858
	±3.623	±2.377	±1.401	±.014
60	153.833	64.986	46.550	.848
	±3.954	±2.254	±1.230	±.014
90	159.917	65.988	46.752	.834
	±4.094	±2.241	±1.211	±.012
120	161.250	68.358	47.123	.828
	±3.734	±3.034	±1.248	±.012

Values ± SE.

Appendix G

Data List

Line 1
ID 1-2
Age 4-5
Yrs Ex 7-8
Mi/wk 10-12
PR Ma 14-16
PR 10K 18-19
Max VO2 21-25
Max HR 27-29
Wt 31-36
70% Max 38-42
D -15 46-49
V -15 51-54
C -15 56-69
T -15 61-64
A -15 66-69
F -15 71-743
La -15 76-79
Line 2
Glu -15 1-4
D 0 8-11
V 0 13-16
C 0 18-21
T 0 23-26
A 0 28-31
F 0 33-36
La 0 38-41
Glu 0 43-46
HR 0 48-49
RPE 30 51-52
D 30 56-59
V 30 61-64
C 30 66-69
T 30 71-74
A 30 76-79
Line 3
F 30 1-4
La 30 6-9
Glu 30 11-14
Se Ef 30 16-18
HR 30 20-22
Ve 30 24-28
RQ 30 30-33
VO2 30 35-39
RPE 60 41-42
D 60 46-49
V 60 51-54
C 60 56-59
T 60 61-64
A 60 66-69
F 60 71-74
La 60 76-79
Line 4
Glu 60 1-4
Se Ef 60 6-8
HR 60 10-12
Ve 60 14-18
RQ 60 20-23
VO2 60 25-29
RPE 90 31-32
D 90 36-39
V 90 41-44
C 90 46-49
T 90 51-54
A 90 56-59
F 90 61-64
La 90 66-69
Glu 90 71-74
Se Ef 90 76-78
Line 5
HR 90 1-3
Ve 90 5-9
RQ 90 11-14
VO2 90 16-20
RPE 120 22-23
D 120 27-30
V 120 32-35
C 120 37-40
T 120 42-45
A 120 47-50
F 120 52-55
La 120 57-60
Glu 120 62-65
Se Ef 120 67-69
HR 120 71-73
Ve 120 75-79
Line 6
RQ 120 1-4
VO2 120 6-10
D Rec 14-17
V Rec 19-22
C Rec 24-27
T Rec 29-32
A Rec 34-47
F Rec 39-42
La Rec 44-47
Glu Rec 49-52
Se Ef Rec 54-56
10K 58-62
Spd Tdm 64-67

```
  2 31 17   70 136 29 68.75 200 128.00 48.13 3   .13 2.00 0.00   .17   .29   .60 1.58
5.56 1   .13 1.50   .60 1.17   .43   .60               56 13 1   .63 2.50 1.00   .50 1.43
 .40 3.86 5.18 340 150 56.88   .91 49.33 12 1   .50 1.50 1.20   .50   .43 1.00 4.00
5.76 330 155 57.44   .87 49.17 11 3   .25 2.17    .60   .17   .14   .60 3.24 4.61 360
159 56.82   .84 51.00 15 0   .25 2.50   .20 1.33 1.71 2.40 1.72 4.31 250 162 55.54
 .83 50.92 3   .38   .33   .67 1.67 0.00 2.80 1.55 4.11 290 29.83 9.80
 3 40 10   47 166 34 65.56 180 146.25 45.69 5 0.00 2.33 0.00 1.83   .14 0.00   .84
6.13 5 0.00 3.00   .20 1.17 0.00 0.00   .63 4.20 54 11 4 0.00 2.83 0.00   .83 0.00
0.00 1.74 4.76 390 129 67.23   .87 43.18 12 4 0.00 2.83 0.00   .67 0.00   .20 1.35
4.68 390 130 66.43   .89 44.01 13 3 0.00 2.17 0.00   .17 0.00   .60 2.20 4.58 380
130 66.49   .86 43.79 14 3 0.00 2.00 0.00   .50 0.00 2.00 1.69 4.32 240 134 67.80
 .80 45.03 5 0.00 1.67 0.00 0.00 0.00 2.00   .98 4.11 240 34.67 7.50
 4 31   6   35 178 35 65.14 188 181.25 45.60 3 0.00 1.67   .20 1.00 0.00   .60 1.91
4.34 3 0.00 1.67 0.00 1.00 0.00 0.00 1.30 5.17 58 14 3 0.00 3.17   .40   .83 0.00
 .40 1.27 3.63 350 145 81.97   .84 48.43 14 4 0.00 3.33   .60 0.33 0.00 0.80 1.81
4.08 340 146 79.06   .84 46.74 15 3 0.00 2.83   .40   .50 0.00 1.80 1.94 4.13 320
149 81.22   .83 48.12 15 2   .38 1.67   .80   .67 0.00 2.80 1.52 3.88 260 153 85.68
 .80 49.74 4 0.00 1.83   .40   .33 0.00 2.80   .50 3.01 230 35.95 8.80
 5 26 10   40 165 33 70.26 195 135.75 49.18 3 0.00 2.00 0.00   .67 0.00 0.00   .88
4.41 3 0.00 2.00 0.00   .17 0.00 0.00 1.20 4.67 52 12 1   .63 1.33   .40 1.17 0.00
1.00                370 165 74.83   .90 52.85 12 3   .50 1.17   .40   .83 0.00 1.00 2.07
4.75 340 164 73.24   .88 51.27 13 3   .13 1.17   .40 1.00 0.00 1.00 1.47 5.51 340
167 72.51   .87 50.30 14 2   .25   .83   .80   .67 0.00 2.00 2.09 3.53 240 171 78.49
 .87 52.45 4 0.00   .83 0.00 0.00 0.00 1.60 1.32 4.81 250 33.90 9.00
 6 24   8   17 172 32 66.17 198 140.00 46.33 3 0.00 1.33   .40 1.17 0.00 0.00 1.40
4.98 3 0.00 1.83   .20 1.00 0.00 0.00 1.38 5.68 71 11 3 0.00 2.00   .20 1.00 0.00
0.00 3.90 4.63 460 171 57.59   .89 48.57 11 3 0.00 1.50   .20   .67 0.00 0.00
        460 172 56.37   .86 46.96 12 1   .13 1.00   .20   .67   .14 1.00 2.65 5.03 420
177 57.92   .85 46.51 13 0   .38   .67 1.00   .67   .29 2.00 1.88 4.52 280 180 60.85
 .83 48.03 1 0.00   .67 0.00   .17 0.00 1.80 1.41 4.45 280 32.80 8.00
 7 30 12   70 144 30 71.59 200 135.50 50.11 2 0.00 1.17   .20 0.00 0.00 1.80 1.03
6.56 2 0.00 1.00 0.00   .17 0.00 1.00 1.25 5.93 75 12 1 0.00   .33   .20   .17 0.00
 .80 1.88 4.20 350 156 64.22   .84 52.26 14 0 0.00 0.00   .20   .67 0.00 1.20
        270 167 62.18   .81 50.95 14 2 0.00   .83 0.00   .17 0.00   .80          310
171 69.34   .84 52.99 15 1 0.00   .17   .20 0.00 0.00 1.80 1.83 4.26 270 175 69.90
 .82 48.88 2 0.00   .17   .40 0.00 0.00 1.60 1.07 4.68 310 30.92 9.00
 8 19   4   40        34 68.71 188 160.00 48.10 2 0.00 2.00   .60 1.00 0.00   .88 1.28
4.21 2 0.00 2.00   .80   .83 0.00   .80                 63 12 1   .38 1.17   .60   .83 0.00
1.00 2.98 5.09 310 156 76.00   .80 53.31 15-1 2.00   .50 1.60 1.00 1.29 2.60 2.29
5.25 130 162 76.31   .81 53.31 16-2 2.25 0.00 2.80 1.67 2.00 3.20 1.53 3.17   80
164 75.09   .79 51.63 16-2 1.25 0.00 2.20 1.83 1.57 3.00 1.00 2.75   70 165 87.81
 .82 53.63-1   .50 0.00 2.20   .67   .14 4.00 1.13 3.38   50 34.13 9.00
 9 40 12   50 171 35 63.48 188 139.00 44.34 3 0.00   .83 0.00 1.00 0.00   .20   .54
4.30 3 0.00   .83   .20 1.00 0.00 0.00                 75 10 2 0.00   .67   .20 0.00 0.00
 .40 2.23 3.37 230 146 57.27   .83 45.26 11 1 0.00   .50 0.00 0.00 0.00   .60 3.37
3.70 220 149 57.79   .83 45.69 13 1 0.00   .50 0.00 0.00 0.00 1.00 1.17 3.42 190
152 54.95   .81 45.42 13 0 0.00   .17 0.00 0.00 0.00 1.40 1.15 3.00 150 156 59.22
 .83 45.79 1 0.00   .17 0.00 0.00 0.00   .80   .72 3.11 140 35.80 7.70
10 31 10   70 170 34 60.07 200 142.50 42.05 5 0.00 2.17   .20   .67 0.00 0.00   .96
4.99 5 0.00 1.83 0.00   .67 0.00 0.00 1.36 4.36 47   9 5 0.00 4.00 0.00   .17 0.00
0.00 1.72 4.94 370 160 66.32   .95 43.96 10 5 0.00 4.00 0.00   .17 0.00 0.00 1.41
5.47 370 168 65.72   .95 44.55 10 4 0.00 4.00 0.00   .50   .17 0.00 1.51 5.20 390
170 64.66   .92 44.23 12 3 0.00 2.17 0.00 0.00 0.00 1.40 1.92 4.27 330 175 60.33
 .93 43.86 3 0.00 2.33 0.00 0.00 0.00 1.60 1.30 4.24 340 34.03 8.30
11 26   8   60 150 31 57.83 188 159.50 40.48 4 0.00 2.33   .20   .50 0.00   .20   .68
3.66 4 0.00 2.83 0.00   .50 0.00 0.00 1.69 4.14 71 12 4 0.00 2.83 0.00 0.00 0.00
 .40 1.70 4.72 230 133 59.46   .79 40.75 12 4 0.00 2.50   .40   .50 0.00   .80
        230 133 59.01   .79 41.29 14 3   .13 2.33 0.00   .67   .14 5.00 1.03 4.83 170
136 64.29   .78 42.30 14 3 0.00 2.83   .60   .50   .14 1.20   .63 3.19 140 150 62.09
 .78 41.67 4 0.00 1.33 0.00 0.00 0.00   .60   .41 4.56 190 31.50 8.20
12 26   5   25        34 63.50 192 160.00 44.45 3   .13 1.67 1.20 2.00 0.00   .60   .64
5.20 3 0.00 2.17 5.00 1.67 0.00   .40   .86 3.62 46 12 2   .63 1.83 1.40 1.14   .14
1.00 3.57 4.18 330 145 64.30   .80 43.78 13 1   .38   .83 1.40   .33   .57 1.80 3.61
4.97 250 156 67.64   .78 46.26 15-1   .75   .67 2.17   .83   .43 2.00 1.39 4.48 210
157 66.79   .77 45.77 17-4   .63   .67 2.40   .67   .43 3.60 1.55 3.60 140 157 66.98
 .77 46.25 1   .38   .33 1.80   .17 1.14 2.60   .86 4.28   60 34.32 8.50
13 35 14   25 154 32 54.56 205 173.25 38.19 2   .13 2.00   .40 2.17 0.00 1.20 1.45
6.34 3 0.00 2.17 0.00 1.67 0.00   .60 1.78 6.28 63 11 3 0.00 2.33 0.00   .83   .14
1.00 2.61 6.62 310 140 60.06   .87 38.50 13 0   .25 1.33 0.00   .33   .14 2.00 2.00
6.87 310 144 58.64   .86 38.40 14 0   .13 1.00   .20 0.00 0.00 2.00 1.51 5.15 270
151 61.78   .85 38.96 14 0   .13   .17 0.00 0.00 0.00 2.60 1.42 4.87 220 157 63.60
 .85 39.23 2   .13   .17 0.00 0.00 0.00 2.00 1.59 5.66 260 32.08 8.60
```